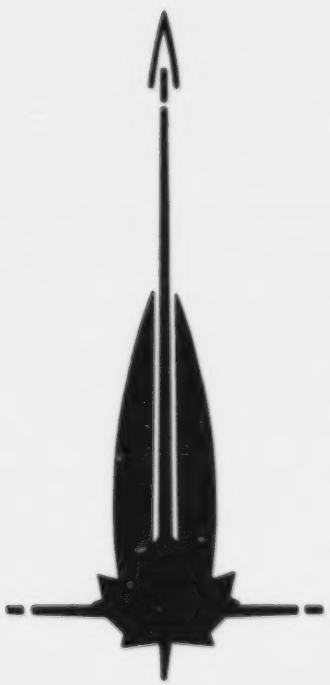
TP 5653 E

german & milne inc.

Prepared for the
Transportation Development Centre
Transport Canada

JULY 1984



Montreal, Quebec
Ottawa, Ontario

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ADVANCED ACIB CONCEPTS
DESIGN STUDY

For the

Transportation Development Centre

File No. 11SD-T8200-3-3536

Prepared by:

Bruce Colbourne

GERMAN & MILNE INC.

July 1984

The contents of this report reflect the view of the Contractor and not necessarily the official views or policies of the Transportation Development Centre, Transport Canada.

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17. Abstract

This report presents the results of a study carried out to identify potential areas of use for Air Cushion Icebreaking Bow (ACIB) technology and to develop concept designs for ACIB's to meet the potential. A survey and a number of interviews were conducted to identify uses. Results of the survey were inconclusive, but interviews revealed two areas of potential for ACIB use. These were the ports and waterways of the St. Lawrence Seaway, the Great Lakes and Lake Melville, Labrador. Potential also exists for ACIB use as assistance to CCG icebreakers operating in the North.

As a result of the study, two concept designs were developed. The first is a 275 tonne craft able to break ice up to 1.1 metres thick. This is a soft cushion diesel powered craft of fairly conventional design. Numerous features have been incorporated to improve operations and maintenance, resulting in a design representing the current state of the art in ACIB development.

The second design is a 1200 tonne rigid sidewall craft able to break ice up to 2 metres thick. This design is conceptual, as a rigid sidewall design requires considerable research and development before a final design can be prepared. This concept represents a starting point for the development of heavy ACIB capability.

Estimated capital and life cycle costs are presented for both designs.

This study concludes that there is potential for ACIB use in Canada which could be fulfilled by machines of the type presented. The 1.1 metre craft could be implemented at this time, but the 2.0 metre craft requires further development work.

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17. Résumé

Ce rapport rend compte de l'étude faite sur les utilisations possibles de la proue brise-glace à coussin d'air (PBCA) et présente des concepts correspondants. D'abord, un sondage a été fait et des interviews personnelles ont été menées. Le sondage n'a pas donné de résultats concluants, mais les interviews ont permis de mettre en évidence deux secteurs d'application intéressants. Ce sont, d'une part, les ports et chenaux de la Voie maritime du St-Laurent, des Grands lacs, et du lac Melville au Labrador, et d'autre part, les régions arctiques où le PBCA pourrait assister les brise-glace déjà sur les lieux.

Deux concepts ont été définis. Le premier concerne un engin de 275 tonnes capable de fracturer des glaces d'une épaisseur maximale de 1,1 mètre. De conception relativement classique à motorisation diesel, et perfectionné pour en accélér la manoeuvre et en faciliter l'entretien, il est à la fine pointe de la technique dans ce domaine.

Le second concerne un engin de 1 200 tonnes, à parois latérales, pouvant briser des glaces d'une épaisseur maximale de 2 mètres; ce concept n'a pas encore atteint le stade des calculs et exige des recherches approfondies avant d'en arriver à un projet définitif. Il n'est que le point de départ pour l'étude d'une nouvelle famille d'engins à coussin d'air lourds.

Le rapport établit en outre le devis estimatif des deux modèles envisagés ainsi que leur coût global sur leur durée de vie.

Le rapport conclut à l'existence au Canada de débouchés possibles pour la proue brise-glace à coussin d'air. Alors que le premier engin pourrait être réalisé dès maintenant, le deuxième nécessite davantage de recherches.

18. Mots-clés	19. Diffusion
Coussin d'air. Brise-glace. Proue brise-glace à coussin d'air, eaux intérieures, arctique	Le CDT dispose d'un nombre limité d'exemplaires.

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PROJECT TEAM

The project team for German & Milne Inc. consisted of:

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Appendix 1: User Requirements Survey

Appendix 2: HCL Report

Appendix 3: Cost Estimate Breakdown

Appendix 4: Concept Design Drawings

BIBLIOGRAPHY

DRAWING PACKAGE ATTACHED

German & Milne Inc. Drawing Nos.

1-7113-101	1-7113-111
1-7113-102	1-7113-112
1-7113-201	1-7113-211
1-7113-202	1-7113-213
1-7113-203	1-7113-214
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1.0 INTRODUCTION

The use of air cushion vehicles for icebreaking is a technology that has been under development in Canada since 1971. Trials have indicated that the use of low speed, non-self-propelled hovercraft in conjunction with vessels offers significant savings in fuel consumption and icebreaking time. These vessel-pushed air cushion craft have been given the generic name Air Cushion Icebreaking Bow (ACIB).

Initial trials of the ACIB concept were performed with modified hover barges in the early and mid-1970's. These trials clearly demonstrated the viability of low speed air cushion icebreaking. In 1981, construction of a dedicated ACIB was completed and operations commenced in Thunder Bay in conjunction with the CCG icebreaker ALEXANDER HENRY.

This first generation ACIB has been used in an operational/ experimental mode for three seasons. The craft has given an excellent demonstration of the potential of the ACIB/ship combination. It has also provided many valuable lessons and pointers in ACIB design and operation. Generally, the craft has been a successful icebreaker but a number of areas requiring improvement have been identified. This has provided incentive to continue the development of the Air Cushion Icebreaking Bow.

Transportation Development Centre in its Request For Proposal 11SD.T8200-3-3536 solicited proposals "to identify and define the needs and requirements of likely Canadian users of icebreaking services and to produce conceptual designs for an air cushion icebreaking bow (ACIB) which could comply with those needs in a cost effective manner". The request identified two classes of ACIB designated as the Inland Waters ACIB capable of breaking ice up to 1 m thick and the Mid-Arctic ACIB capable of breaking ice up to 2 m thick.

German & Milne Inc. were awarded the contract to perform the concept designs early in 1984. This report presents the results of the study to determine potential users and their requirements and the subsequently developed concept designs.

Under the main contract awarded to German & Milne Inc., skirt system design and model testing were sub-contracted to Hovercraft Consultants Ltd. of Southampton, England. The report presented by HCL giving the results of their investigations is contained in Appendix 2.

A number of potential users were identified during the survey, although none of the respondents indicated a willingness to assume the cost of the ice management services. The areas showing promise for Inland Waters ACIB use were Great Lakes and St. Lawrence Seaway ports and Lake Melville, Labrador. For the Mid-Arctic ACIB, the major user is predicted to be the Canadian Coast Guard with some additional potential for use on Beaufort Sea oil exploration operations.

The Inland Waters ACIB concept is a circular craft with a cushion diameter of 17.5 metres and a maximum all-up weight of 275 tonnes. The craft is powered by two main diesel engines and employs a liquid ballast system for weight adjustment.

The Mid-Arctic ACIB concept is a rigid sidewall craft with a length of 27 metres and a beam of 32 metres. Lift power is provided by four main diesel engines and the maximum all-up weight is 1200 tonnes.

Capital and life cycle costs for the two craft are estimated as follows:

	Capital Cost	Yearly Costs	Cost Recovery per year
Inland Waters ACIB	$3,162,000.	$ 130,000.	$ 583,500. (25 years)
Mid-Arctic ACIB	$7,092,000.	$1,145,000.	$2,155,000. (20 years)

The concept design study revealed a number of areas requiring further research. Notable amongst these was the question of ACIB notching and its effects on overall resistance and track clearing. Another subject is the breaking pattern of ice under an ACIB. More work in these areas would supply data to settle the contentious issues of craft planform and notching.

The introduction of the rigid sidewall concept calls for further work in the field of ice/sidewall interaction before the concept can be further developed. As such, the concept has been presented as a starting point for future development.

2.0 POTENTIAL ACIB USERS AND REQUIREMENTS

In the identification of potential Canadian users and requirements for air cushion icebreaking, a number of approaches were taken. Initially a survey of Port Managers and ferry operators within the defined Eastern Canadian and lower Arctic geographic zones was undertaken. Basic environmental data for the areas of interest was also gathered independently of the survey. This data was used in the formulation of the performance parameters for the two ACIBs. Finally, a number of parties were contacted directly to assess their interest in the use of air cushion icebreaking. Taken together, these items clearly established the performance requirements and identified a number of potential users.

The mail survey of port and ferry operators involved sending 20 questionnaires to the ports and operators listed in Appendix 1. Of these, five replies were received from Port Managers only. In general the replies indicated that little need was foreseen for air cushion icebreaking and in no case was the Port Authority willing to consider the purchase or operation of an icebreaking craft. In cases where icebreaking is required on a significant scale, the service is provided by Transport Canada. It would seem that the ports are unwilling to undertake what is presently offered to them free of charge.

Response to the survey was low particularly in the case of ferry operators. This was probably because most of the operators surveyed run seasonal tourist oriented ferries along the St. Lawrence Seaway and the Great Lakes.

Environmental data for the geographic area under consideration was collected from Environment Canada and is given in reduced form in Tables 1 through 3. The table of ice thicknesses clearly shows that average ice thicknesses are less than 1 m and that the maximum recorded values rarely exceed 1 m by more than 10%. Snowfall and

temperature readings serve to establish expected environmental characteristics for design purposes.

Direct contact through visitation or telephone was established with the following parties:

- Mr. David Williams, CN Marine
- Mr. D. Figurski, Port of Churchill
- Mr. G. Desgagnés, Port of Chicoutimi
- Mr. Mike Mulcahey, Newfoundland Department of Development
- Mr. Ivan Ford, Newfoundland Department of Development

It was thought to be likely that these people may have a special interest in the use of air cushion icebreaking.

CN Marine indicated that they felt that their problems with ice were neither severe enough nor of sufficient duration to justify the use of an ACIB. The most frequent cause of ice induced service interruption for CN is high pressure pack ice and the effectiveness of an ACIB under these conditions is questionable.

The Port of Churchill could foresee little use for ice management services in the harbour as the Port is usually clear before Hudson Bay is navigable and the Coast Guard provides icebreaking services when required.

Mr. Desgagnés of the Port of Chicoutimi felt that considerable benefit could be derived from the use of an ACIB in that area. The ACIB could be used to extend the navigational season resulting in considerable economic benefit. In general he felt that the ACIB would probably be a paying proposition for the area and indicated a strong interest in the idea.

The Newfoundland Department of Development indicated that there was strong potential for the use of an ACIB for winter navigation in Lake Melville, Labrador. Particular interest was expressed in the

(All Measurements in cms)		ICE THICKNESS																							
AREA	OVERALL MAXIMUM	AUGUST		SEPT.		OCTOBER		NOV.		DECEMBER		JANUARY		FEBRUARY		MARCH		APRIL		MAY		JUNE		JULY	
		MAX	MEAN	MAX	MEAN	MAX	MEAN	MAX	MEAN	MAX	MEAN	MAX	MEAN	MAX	MEAN	MAX	MEAN	MAX	MEAN	MAX	MEAN	MAX	MEAN	MAX	MEAN
UNDER BAY	100(1963)	0	0	0	0	0	0	0	0	60	27.3	67	43.9	91	63.2	100	76.0	94	70.8	0	0	0	0	0	0
LSON BAY (Oshawa)	87(1977)	0	0	0	0	0	0	0	0	3	3.0	45	25.0	87	37.8	71	46.0	58	58.0	0	0	0	0	0	0
RONTO																									
LLAND CANAL (Hamilton)	71(1963)	0	0	0	0	0	0	0	0	0	0	44	14.1	62	26.5	71	25.0	0	0	0	0	0	0	0	0
NTREAL (A7-Station)	91(1971)	0	0	0	0	0	0	0	0	23	23.0	61	35.2	89	53.6	91	58.8	0	0	0	0	0	0	0	0
GOTVILLE (Quebec)	102(1972)	0	0	0	0	0	0	6	5	76	27.8	79	53.6	94	73.8	102	67.1	0	0	0	0	0	0	0	0
EST BAY (Windsor)	61(1977)	0	0	0	0	0	0	3	3	25	10.8	56	24.0	61	33.5	61	24.0	0	0	0	0	0	0	0	0
NGAN (Sept Isles)	89(1979)	0	0	0	0	0	0	34	34	53	41.8	66	48.0	78	67.1	89	66.1	75	64.7	51	46.0	0	0	0	0
TASHQUAN (Sept Isles)	91(1976)	0	0	0	0	0	0	15	10	37	28.2	63	30.0	72	44.3	91	54.4	81	81.0	0	0	0	0	0	0
COLET (Trois Rivières)	104(1978)	0	0	0	0	0	0	16	8.7	51	24.5	66	43.0	91	61.9	104	69.7	81	69.8	0	0	0	0	0	0
MMERSIDE (Northumberland Str)	73(1977)	0	0	0	0	0	0	8	2.8	33	14.3	60	25.9	73	46.5	69	40.7	25	21.7	0	0	0	0	0	0
ANC SABLON (Belle Isle)	109(1976)	0	0	0	0	0	0	28	28	57	38.3	81	50.0	94	68.5	107	75.1	85	53.2	79	34.5	0	0	0	0
OSE BAY (Lake Melville)	122(1978)	0	0	0	0	4	4	68	14.3	66	35.7	84	53.5	94	68.0	107	79.7	118	82.3	122	52.9	0	0	0	0
RNER BROOK	62(1974)	0	0	0	0	0	0	0	0	12	8.0	22	11.4	43	24.4	62	38.7	61	52.0	0	0	0	0	0	0
AND LAKE (Sydney)		MAXIMUM 96.5						MEAN 58.4				METHOD OF MEASUREMENT UNKNOWN													
URCHILL	206(1976)	0	0	0	0	0	0	58	35	99	67.2	132	101.5	178	131.6	193	153.5	206	166.5	198	161.0	168	153.5	0	0

TABLE 2.1: ICE THICKNESS RECORDINGS

Measurements in cms.
T = Less than 0.1 cm.

SNOWFALL

Max.-Max. snowfall in 24 hrs. during time records kept.

AREA	AUGUST		SEPTEMBER		OCTOBER		NOVEMBER		DECEMBER		JANUARY		FEBRUARY		MARCH		APRIL		MAY		JUNE		JULY	
	MAX	MEAN	MAX	MEAN	MAX	MEAN	MAX	MEAN	MAX	MEAN	MAX	MEAN	MAX	MEAN	MAX	MEAN	MAX	MEAN	MAX	MEAN	MAX	MEAN	MAX	MEAN
THUNDER BAY	0	0	0.8	T	16.3	3.3	34.5	29.8	42.0	46.2	51.6	48.4	33.5	30.7	37.8	34.2	24.1	16.2	21.6	4.2	T	0	0	0
OSHAWA WPCP (Wilson Bay)	0	0	0	0	6.6	0.8	17.8	9.0	26.0	36.7	27.9	46.4	16.8	25.4	15.2	24.2	20.3	6.4	T	0.1	0	0	0	0
TORONTO	0	0	T	0	12.2	0.6	30.5	7.4	48.3	33.9	39.9	36.4	45.7	28.5	40.6	24.7	21.1	7.6	7.6	0.1	T	0	0	0
HAMILTON A (Welland Canal)	0	0	0	0	23.6	1.3	14.2	11.5	35.6	34.3	43.2	39.4	25.4	30.1	20.3	20.1	29.2	6.4	T	0	0	0	0	0
MONTREAL INT'L A	0	0	6.1	0	14.2	1.7	30.5	33.9	37.8	58.8	32.8	52.7	39.4	53.6	43.2	35.7	25.7	9.7	21.8	1.7	0	0	0	0
QUEBEC A. (Begotville)	0	0	T	T	17.3	4.4	30.5	11.5	35.6	86.1	32.3	77.5	29.2	70.2	43.9	54.2	33.0	16.2	7.1	0.9	0.3	T	0	0
WINDSOR A. (Brest Bay)	0	0	T	0	2.4	0.1	34.8	50.8	32.3	28.6	23.9	30.2	36.8	22.8	22.4	20.0	14.2	4.2	0.5	T	T	0	0	0
SEPT ISLES (Hingan)	0	0	T	T	28.2	10.6	45.4	34	52.1	89.1	48.3	93.4	41.9	74.0	50.8	70.0	43.4	33.0	29.2	6.0	0.5	T	0	0
SEPT ILES (Moteshquan)																								
TROIS RIVIERES (Nicolet)	0	0	0	0	10.2	1.1	41.1	23.5	48.3	70.1	38.1	57.9	40.6	55.4	41.9	42.2	43.7	10.3	12.7	0.9	0	0	0	0
SUMMERSIDE (Northumberland Str)	0	0	T	0	20.3	2.1	27.2	17.0	44.2	60.4	53.6	66.7	38.9	55.9	40.9	54.9	37.6	24.0	8.4	1.8	T	0	0	0
BELLE ISLE (Blanc Sablon)	0	0	25.7	1.2	19.1	8.6	61.0	30.6	39.4	43.9	50.8	41.7	35.6	39.8	38.1	41.7	40.6	36.0	30.5	9.5	12.7	2.5	T	0
GOOSE A. (Lake Melville)	T	0	19.0	4.0	27.7	24.7	40.6	57.0	35.6	73.6	35.6	80.0	39.6	60.6	38.6	74.6	28.3	48.6	33.8	18.4	24.1	3.7	T	0
CORNER BROOK	0	0	T	0	16.5	6.3	38.1	38.8	43.2	99.7	48.3	104.4	61.0	73.8	26.7	57.9	29.0	25.0	17.8	4.8	2.5	0.2	0	0
CHURCHILL	T	0	17.5	6.4	36.1	29.3	35.1	41.6	21.8	22.8	16.0	16.9	12.7	14.6	22.6	18.6	25.4	22.3	47.6	19.5	15.7	3.5	T	0

TABLE 2.2: SNOWFALL RECORDINGS

(C.O. 7113)

easurements in °C - Mean Daily Temperatures

TEMPERATURE

Min.-Extreme Min. Temp. during time records kept.

AREA	AUGUST		SEPTEMBER		OCTOBER		NOVEMBER		DECEMBER		JANUARY		FEBRUARY		MARCH		APRIL		MAY		JUNE		JULY	
	MIN	MEAN	MIN	MEAN	MIN	MEAN	MIN	MEAN	MIN	MEAN	MIN	MEAN	MIN	MEAN	MIN	MEAN	MIN	MEAN	MIN	MEAN	MIN	MEAN	MIN	MEAN
UNDER BAY	-1.1	16.4	-8.3	11.1	-13.3	5.7	-30.6	-2.6	-37.8	-11.1	-41.1	-15.4	-40.0	-13.0	-36.7	-6.3	-22.2	2.5	-8.9	8.8	-2.8	14.0	0	17.6
HAWA WPCP (Wilson Bay)	4.4	20.3	-0.6	19.8	-7.8	15.9	-12.0	9.8	-29.0	4.1	-27.8	-5.6	-27.0	-4.9	-20.0	-0.2	-13.3	6.4	-2.8	11.9	1.1	17.4	7.8	20.3
RONTO	4.4	21.2	-2.2	17.1	-8.9	11.0	-20.6	4.9	-30.0	-1.6	-32.8	-4.6	31.7	-3.9	-26.7	0.7	-15.0	7.6	-3.9	13.6	-2.2	19.1	3.9	22.0
MILTON A (Welland Canal)	1.1	20.0	-2.2	15.7	-7.8	9.4	-12.8	3.4	-26.8	-3.4	-27.8	-6.4	-26.1	-6.3	-22.0	-0.8	-12.8	6.1	-3.9	12.6	1.7	18.0	5.6	20.5
NTREAL INT'L A	3.3	19.6	-2.2	14.8	-7.2	8.7	-19.4	2.0	-32.4	-6.9	-37.8	-10.2	-33.9	-9.0	-29.4	-2.5	-15.0	5.7	-4.4	13.0	1.1	18.3	7.0	20.9
EBEC A. (Bagotville)	2.2	17.5	-4.8	12.6	-10.0	6.6	-24.0	-0.2	-32.2	-9.0	-35.0	-12.1	-36.1	-10.8	-30.0	-4.5	-18.9	3.3	-7.8	10.8	-0.6	16.4	3.9	19.1
NDSOR A. (Brest Bay)	5.6	21.3	-1.1	17.4	-5.0	11.1	-15.6	4.4	-23.3	-1.9	-26.1	-4.9	-22.2	-3.8	-19.4	1.2	-9.4	8.1	-2.8	14.2	2.8	19.7	5.6	22.4
PT ISLES (Mingan)	-0.6	14.1	-6.5	9.3	-12.8	3.6	-28.9	-2.5	-36.1	-11.0	-43.3	-14.0	-38.3	-12.5	-31.7	-6.6	-24.4	0	-11.7	5.9	-2.8	11.7	1.7	15.2
PT ILES (Natashquan)																								
OIS RIVIERES (Nicolet)	0	18.1	-6.7	13.3	-11.7	7.4	-23.9	0.4	-35.6	-9.0	-38.3	-12.1	-38.9	-10.8	-30.0	-3.9	-19.4	4.4	-7.8	11.9	-1.1	17.2	3.9	19.7
MERSIDE (Northumberland Str)	4.4	18.4	-0.1	14.1	-5.6	8.6	-13.3	3.0	-25.6	-4.0	-27.2	-7.2	-26.1	-7.2	-23.9	-2.8	-12.2	2.6	-5.0	9.0	0	14.9	6.7	18.9
LE ISLE(Blanc Sablon	-1.7	10.1	-3.3	6.8	-11.1	2.4	-21.1	-1.2	-34.4	-6.8	-35.0	-9.6	-34.4	-9.8	-28.9	-6.5	-23.3	-2.7	-15.6	1.1	-7.2	5.0	-3.9	9.3
SE A (Lake Melville)	0	14.3	-6.7	9.1	-15.0	22.7	-25.0	-3.8	-36.7	-13.0	-38.9	-16.4	-39.4	-14.5	-35.6	-8.6	-25.6	-1.7	-15.0	5.0	-4.0	11.3	0.6	15.8
NER BROOK	0	16.4	-2.8	12.1	-7.8	7.1	-16.1	2.9	-20.6	-2.6	-31.7	-5.1	-31.7	-6.3	-29.4	-2.6	-15.6	2.3	-7.2	7.1	-4.4	12.6	1.1	17.0
RCHILL	-2.2	11.3	-11.7	5.4	-24.4	-1.5	-36.1	-12.1	-40.0	-22.2	-45.0	-27.5	-45.4	-25.9	-43.9	-20.4	-33.3	-10.1	-21.7	-1.5	-9.4	6.2	-2.2	11.8

TABLE 2.3: TEMPERATURE RECORDINGS

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ACIB's capability in restricted areas for clearing a channel into Goose Bay. It was felt that the ACIB would be a useful ice management tool in the event that year round navigation on Lake Melville was established.

The intent of this phase of the project was to establish potential Canadian users for the ACIB and to identify the performance requirements for the two types of ACIB.

With regard to potential users, the survey identified two areas of high potential. It is, however, clear that most of the ice management in Canada is performed by the Canadian Coast Guard on request. Logically, the Coast Guard is the most likely user of ACIB technology. Unless federal policy is to be changed to a user pay system for ice management services, parties presently requiring assistance with ice problems are not going to undertake ice management programs of their own. It would seem that Coast Guard will be the major beneficiary of ACIB development.

In the area of performance requirements, the environmental data gathered indicates that for most areas a 1.1 m ice thickness capable craft would be adequate. Maximum ice thicknesses experienced in the lower Arctic are on the order of 2 m but the major user of this size of ACIB would again be the Canadian Coast Guard. The data supports the development of both the 1 m and 2 m capable craft for the intended operational areas. It would seem though that the 1 m craft with a small increase in capability would have a wider range of application. For this reason, the Inland Waters ACIB was upgraded slightly to a 1.1 m capable craft. This slight increase will allow the craft to handle all surveyed inland and sub-Arctic regions.

3.0 MISSION PROFILE

3.1 INLAND OR COASTAL WATERS ACIB

The Inland Waters ACIB was designed for use on inland waterways or coastal areas. The geographical area covered by this definition includes the St. Lawrence Seaway, the Great Lakes, and East Coast Canada as far North as Lake Melville. These craft will be used for ice management in harbours and along relatively short sea lanes with the host ship for these applications being a tugboat or a CCG light or medium icebreaker.

This mode of operation will involve encounters with salt and fresh water ice in thicknesses rarely exceeding 1 m and of flexural strengths up to 600 kPa. Ridge sail heights typically equal to ice thickness may be expected.

Required track width could be up to 33 m for large lakers but a narrower track is desirable for operations in restricted harbours. For wider tracks, double passes could be made to open up suitable lanes. This is in keeping with the near-base operational profile.

Environmental conditions are expected to range from fair and mild spring weather to severe winter conditions. In general, it is likely that operations will be limited to Beaufort Force 6 conditions (wind speed approx. 26 knots) or better. The expected ambient temperature range is minus 45°C to 20°C. Design temperature range has been expanded to allow for unexpected conditions.

It may be required to transport the ACIB over long distances between locations and in the interest of structural integrity, the craft was designed to be transported while on hover or by barge.

3.2 MID-ARCTIC ACIB

The Mid-Arctic ACIB was designed for use in the Canadian Arctic North of the 55° parallel. The primary uses of the craft are predicted to be port and anchorage clearance, long-range icebreaking, and ice management around drill ships and rigs. The host ship for these applications will be a CCG medium or heavy icebreaker or an offshore supply vessel of the type typically used in the Arctic.

These operations will be primarily in salt water ice up to 2 m thick with flexural strengths up to 600 kPa. Ridging with sail heights on the order of 1 to 1.5 m may be expected.

A track width of 30 m to 35 m is desirable for clearing lanes in a single pass. It is not expected that the requirement for manoeuvrability in restricted areas would be as stringent for the Arctic ACIB as for the Inland Waters ACIB.

Design environmental conditions will be those typical of the Canadian Arctic with an ambient temperature range of minus 60°C to 20°C.

As in the case of the Inland Waters ACIB, the Arctic craft was designed to be transported while on hover or on a separate barge.

3.3 PERFORMANCE SPECIFICATION

Based on the mission profiles in Section 1, the following performance parameters were developed for the two ACIB types.

3.3.1 Inland or Coastal Waters ACIB

- Cushion dimensions:
  - Length — 15 m (min.)
  - Beam — 18 m (approx.)

o	Hover height (to hard structure)	1.2 m (min.)
o	Maximum cushion pressure	11 kPa
o	Maximum operating speed with host vessel	7 knots
o	Endurance	12 hrs. at full power without refuelling.
o	On cushion stability	0.5% CP shift/degree roll & pitch.
o	Off cushion buoyancy	30% reserve minimum.
o	Off cushion stability	1.0 m GM
o	Floodability	Single compartment; bottom puncture.

3.3.2 Mid-Arctic ACIB

o	Craft dimensions:	
	- Length	20 m (min.)
	- Beam	32 m (approx.)
o	Hover height (to hard structure)	1.6 m (min.)
o	Maximum cushion pressure	20 kPa
o	Maximum operating speed with host vessel	7 knots
o	Endurance	24 hrs. at full power without refuelling.
o	On cushion stability	0.5% CP shift/degree roll & pitch.
o	Off cushion buoyancy	20% reserve minimum.
o	Off cushion stability	1.0 m GM
o	Floodability	Single compartment; bottom puncture.

3.4 GENERAL

In this section and those that follow, the specified items apply to both types of ACIB.

3.4.1 Icing

The craft shall be designed to minimize spray both internal and external to the plenum. Air ducting shall be arranged to minimize spray creation and spray suppression skirts shall be included. Bottom structure shall be as smooth as possible to minimize ice accretion.

3.4.2 Maintainability

In general, a rugged low maintenance craft is required. In areas where maintenance is required, it shall be kept in mind that the work may have to be performed in extremely cold conditions.

3.4.3 Skirt Maintenance

If possible without undue complication to bottom structure and skirt attachment, the skirts shall be arranged to allow replacement over water. Failing this, the skirts shall be designed to be self-sealing in the event of the loss of up to three segments.

3.4.4 Ballast System

A system allowing adjustment of the craft all-up weight and the quick reduction of the weight in an emergency shall be provided. Crash discharge times of 15 minutes for the Inland Water ACIB and 45 minutes for the Mid-Arctic ACIB shall be provided.

3.4.5 Transportability

In general the structural integrity of the craft must be maintained. The craft shall be designed to be transported by barge or in such a way that it can act as a barge by itself, either on or off hover.

3.5 GENERAL LAYOUT

3.5.1 Machinery

3.5.1.1 GENERAL

Main engines, auxiliary machinery and deck machinery shall be marine quality machinery designed for service at ambient temperatures ranging from minus 60°C to 40°C. All systems shall be specified and designed with ease of maintenance in mind. Engine redundancy shall be provided to the point where the failure of one engine shall not reduce hover height by more than 25%.

3.5.1.2 MAIN AND AUXILIARY ENGINES

Main and auxiliary engines shall be marine diesel engines designed for continuous service and for operation on regular marine diesel oil.

3.5.1.3 DECK AND AUXILIARY MACHINERY

Insofar as is practical, all deck (winches, etc.) and auxiliary (ballast pumps, etc.) machinery shall be electrically driven to allow all machinery to be driven from a single power system. Transit and attachment winches shall be operable from a point near the winch and from a central control point.

3.5.1.4 ELECTRICAL SYSTEM

The electrical system shall be provided with two generators, each of which shall be capable of providing 110% of the power

required for normal operations. A separate auxiliary power unit shall be provided for heating, lighting, battery charging and maintenance, when the main engines are shut down.

3.5.1.5 MACHINERY ENCLOSURE

A lighted, heated and ventilated machinery enclosure shall be provided to allow repair and maintenance on all machinery in inclement weather. Provision shall be made for the automatic closing of cooling air louvres, inlet and outlet, in event of fire.

3.5.1.6 FANS

Provision shall be made for the automatic closing of air inlets in event of engine failure. Provision shall also be made to prevent water from entering the ducts when the ACIB is off cushion, and particularly if it is being towed off cushion.

3.5.1.7 STORES AND WORKSHOP

An area adjacent to the machinery space shall be provided for a workshop including the safe storage of tools and maintenance materials including oil and paint.

3.5.2 Ballast System

A liquid ballast system shall be provided to allow convenient adjustment of trim and all-up weight. This system shall have provision for quick discharge of ballast in an emergency.

3.5.3 Jacking System

An integral jacking system shall be provided for the Inland Waters ACIB which shall enable the craft to lift itself while off cushion and located on a hard (concrete) surface, to a height where the skirts hang without touching the surface. The high weight of the Mid Arctic ACIB may require an external jacking or beaching system.

3.5.4 Flexible Skirts

Flexible skirts shall be of a material able to withstand 120% of the maximum design air pressure without significant ($>5\%$ at 11 kPa or $>10\%$ at 20 kPa) distortion in any dimension.

3.5.5 Host Vessel Attachment

A system for attaching the ACIB to the bow of a host vessel shall be provided. This system should not require any modifications or permanent attachment to the host ship and should be adaptable to a number of expected hosts. The system should minimize yaw, sway and surge motions while allowing freedom in heave pitch and roll.

3.5.5.1 HOST VESSEL ACCESS

Access ladders or stairways shall be provided to allow crew to move to and from the ACIB and the host vessel.

3.5.6 Control, Monitoring and Communications

3.5.6.1 CONTROL ROOM

A control room shall be provided on the ACIB from which all machinery and systems can be monitored and controlled. This room shall be fitted with windows and situated to give a 360° field of view on the ACIB.

3.5.6.2 MONITORING SYSTEM

A monitoring system shall be provided to give status and indicate emergency conditions for all machinery, equipment, ballast and fuel systems. Cushion pressure indication shall also be provided.

3.5.6.3 REMOTE CONTROL SYSTEM

A remote control system shall be provided to allow the control and monitoring of major systems from the host ship bridge without the requirements for personnel on the ACIB (unmanned operation).

3.5.6.4 COMMUNICATIONS SYSTEMS

A communications system shall be provided between the host ship bridge and the ACIB control room. A public address system shall be provided on the ACIB which can be operated from the control room or the host ship bridge.

3.5.7 Surface Coatings

3.5.7.1 GENERAL

All surfaces inside and out shall be coated to protect the surface and prevent deterioration.

3.5.7.2 DECK COVERINGS

All deck surfaces shall be provided with a high quality non-slip surface.

3.5.7.3 BOTTOM COVERING

Bottom areas and other areas subject to spray shall be coated with a smooth, low friction coating to reduce ice accretion.

3.5.8 Under Deck Access

Access shall be provided to all tanks and void areas for inspection and maintenance. In addition, access to the plenum shall be provided through an air lock from the deck for skirt and bottom structure inspection.

3.5.9 Under Deck Inspection

A system of lights and a video camera shall be provided for plenum inspection when the craft is underway.

3.5.10 Exterior Lighting

Floodlighting shall be provided on all exterior deck areas for safe night operation.

3.5.11 Ground Access

A ladder or stairway shall be provided to allow access from the craft to the ground or a dock while on or off cushion.

3.6 STANDARDS

3.6.1 Structural Standards

Hard structure shall be designed in accordance with the ABS Rules for Building and Classing Steel Barges (or other recognized Classification Society) or the Canadian DOT Certification Requirements for Non-Self-Propelled Air Cushion Platforms, whichever is the more stringent.

3.6.2 Material Standards

Materials specified shall be those approved by the CSA for ship construction, marine or heavy industrial use in low temperatures.

3.6.3 Safety Standards

The ACIB shall be designed in accordance with the Canadian DOT Certification Requirements for Non-Self-Propelled Air Cushion Platforms.

3.6.4 Habitability

Machinery and control spaces shall be provided with adequate heat, light and ventilation to maintain comfortable working conditions.

Noise levels in machinery spaces should not exceed 95 dB(A) and those in the control room and workshop should not exceed 80 dB(A).

3.6.5 Railings and Fan Guards

A safety railing shall be located around the deck perimeter and on the host ship access ladder or stairway. Guards shall be located in way of lift or other fan intakes to prevent the ingestion of foreign objects or danger to crew. The deck railing shall be removable.

4.0 INLAND WATERS ACIB DESIGN DESCRIPTION

The Inland Waters ACIB has been designed for operation in ice of thicknesses up to 1.1 m. The craft is similar in size and capability to the CCG ACIB through which valuable experience has been gained. Air cushion icebreaking at this performance level presents no major technological challenges and in all cases the experience gained with the CCG ACIB has been incorporated into the new design.

As a result of this, the Inland Waters ACIB has been designed with operational and performance improvements uppermost in mind. Emphasis has been placed on producing a serviceable and reliable design without introducing radical or complex technology. The craft has been kept simple and low cost both in terms of construction and in terms of operations and maintenance. Where choices between the two have been necessary, operational and maintenance considerations have been favoured.

This design philosophy has resulted in a rugged craft of high reliability. The higher capital cost should be recovered over the life of the craft through reduced maintenance and more efficient operations. In general, this design offers efficient performance and improved operations under a demanding working environment. Individual aspects of the design are detailed in the following sections.

4.1 PLANFORM AND LAYOUT

The circular planform was chosen for a number of reasons. Experience in Thunder Bay has indicated that ice under an ACIB falls in the classical pattern of radial and circumferential cracks. Theory developed by Nevel and Carter verify this observation. With this breaking pattern, an advancing ACIB is presented with a more or less semi-circular ice edge. A circular planform also offers the best ratio of lifting area to periphery resulting in the most efficient use of lift air power. Finally, the use of a circular

planform allows the installation of a single skirt segment type all around the craft. With this feature, only one type of spare skirt need be kept on hand, reducing the expense of maintenance.

The layout of the craft has been arranged to keep the craft centre of gravity as low as possible. Ballast is carried in double bottom tanks which give a high degree of safety in the event of a bottom puncture. The engines are mounted below the main deck to keep weight low and to provide an enclosed machinery space.

Insofar as possible, deck space has been kept clear and flat enabling the craft to be used as a working platform in the off season.

Fuel is carried in an internal tank which is not subject to damage in the event of craft bottom damage thus reducing the chance of an oil spill.

A cushion notch for host vessel attachment has not been included in the design as no evidence has been found in the available literature to indicate that the inclusion of this type of notch gives any benefit in terms of overall pushing resistance or clearing of broken ice out of the vessel track. The increased cost and operational complexity of the notch installation override the benefit of a slightly more secure and better positioned pushing point. The notch has been replaced with a pushing yoke attached to the stern of the craft external to the cushion. This yoke is designed to allow the ACIB freedom in pitch and heave, while yaw, sway and surge motions are restrained with attaching cables.

An elevated control room with a 360° view of the craft is provided to allow the operation and monitoring of all equipment from a single location.

4.2 SKIRT CONFIGURATION

The circular planform permits the use of a common skirt segment all around the craft. Scooping in the rear segments is prevented by a separate 'drag sheet' which requires no alteration to the individual skirt segments. Skirt mounting is arranged on continuous rails with all retaining and sealing hardware positioned above the light waterline. This allows skirt replacement in a deballasted floating condition with the assistance of a special gantry crane/ removal rig. Space for the storage of skirts is provided on the craft. These items are in keeping with a philosophy of craft self-sufficiency requiring minimal shore base facilities.

Main skirt segment shape has been kept as simple as possible. The knuckleless design results in a small light skirt which can be laid out flat or rolled for storage. Skirt segments are mounted entirely beneath the craft reducing the possibility of damage due to encounters with vessels or docksides.

A jacking system is provided allowing the craft to lift itself while on solid, dry land to the point where the skirts hang free for inspection or maintenance.

4.3 POWERING AND AIR DELIVERY

Lift power is provided by two main diesel engines driving centrifugal fans. Each engine will have sufficient power to maintain 75% hover height in the event of failure of the other engine. Air feed to the cushion is through a peripheral duct which opens into the top of the skirt segments. This system provides low velocity air for the cushion and ensures positive skirt inflation. It also serves to reduce undercraft spray and results in a uniformly depressed water surface under the craft.

Electric power for winches, ballast heating and services is provided by generating sets driven by the main engines. An auxiliary

generating set is provided for use when the main engines are not operating. With the exception of the jacking system, all machinery including deck winches are electrically powered. This eliminates the need for a number of different power supplies and reduces maintenance requirements. The jacking system is electro-hydraulic.

4.4 BALLAST SYSTEM

A liquid ballast and trim system is included in the craft double bottom. Heated water will be used as the ballast medium and tanks will be insulated to reduce energy consumption. Heating is through electric immersion heaters. Ballast and trim controls are operable from the control room and crash discharge capability is provided for emergencies or to allow quick deballasting at the end of daily operations.

A ballast system of this type provides the required flexibility for operations in differing ice thicknesses. The use of untreated water reduces the pollution hazard and eliminates the requirement for storing ballast on board the host ship.

5.0 INLAND WATERS ACIB DESIGN SPECIFICATION

5.1 GENERAL

This specification and the associated drawing package presents the concept design for the Inland Waters ACIB. The intent of this specification is to identify the major components of the ACIB system to establish the feasibility of the design and to allow a reasonable cost estimate for the finished craft.

The specification is broken down into three sections: hull, machinery and skirt system. The following drawings and diagrammatics are illustrative of the concepts and support the specification:

	G&M Dwg. No.
o General Arrangement	1-7113-101
o Structural Arrangement & Sections	1-7113-102
o Fuel Oil System Diagrammatic	1-7113-201
o Ballast System Diagrammatic	1-7113-202
o Engine Cooling System Diagrammatic	1-7113-203
o Bilge System Diagrammatic	1-7113-204
o Electrical System Single Line Diagrammatic	1-7113-301

In the following sections, the ACIB systems are described. In all cases the craft has been designed to meet the performance specifications (Section 3.0).

5.2 HULL SPECIFICATION

5.2.1 Principal Particulars

The Inland Waters ACIB shall be a circular planform craft with the following principal particulars:

o Craft outside diameter	23.6 m
o Cushion diameter	17.5 m
o Craft depth to main deck	3.25 m
o Hard structure clearance (on hover)	1.25 m(Min)

- o Maximum cushion pressure — 11 kPA
- o Maximum all-up weight — 275 tonnes

5.2.2 General Arrangement

The design General Arrangement is presented on G&M Drawing No. 1-7113-101. This drawing illustrates the location and arrangement of the major components on the ACIB.

5.2.3 Design Standards

The craft has been designed in accordance with the Canadian Department of Transportation Guide to Certification Requirements for Non-Self-Propelled Air Cushion Vehicles. Structural design is in accordance with Lloyd's Rules for Building and Classing Steel Ships.

5.3 HULL STRUCTURE

5.3.1 Materials

The ACIB hull has been designed for construction with CSA G40.2133T steel of 304 mPa minimum yield strength.

5.3.2 Hull and Superstructure

The main hull structural arrangement is detailed on G&M Drawing No. 1-7113-102. This drawing illustrates the framing system and plating thicknesses as well as showing the location and arrangement of deck structures.

5.4 OUTFIT AND FURNISHINGS

No accommodation will be provided on board the craft. An area adjacent to the machinery room will be provided with a desk and chair and a second area adjacent will be provided with a stand alone chemical toilet.

The control room will be provided with two high chairs for the use of the operators.

5.5 DOORS, HATCHES AND WINDOWS

All doors are to be of accepted marine standards and shall be located where indicated on the General Arrangement drawing.

A hatch shall be fitted in the deck, opening into a skirt storage locker and into the central machinery compartment.

The control room windows shall be fixed except for two (2) opening windows for ventilation. All windows are to be safety glass. Electric motor driven clear view screens shall be fitted, one in the centre of each side of the control room.

5.6 INSULATION

The control room shall be fitted with 25 mm of thermal insulation all around.

Ballast tanks shall be insulated with 100 mm of thermal insulation suitable for continuous immersion in seawater. This insulation shall be applied to the inside of all tank surfaces.

5.7 PAINT AND SURFACE COATINGS

All paint and coating systems shall be of good quality for marine applications, supplied by an experienced manufacturer, International Paints (Canada) Ltd. or equivalent.

All metal surfaces shall be prepared in accordance with the paint manufacturer's recommendations and primed with an anti-corrosive primer.

Void spaces shall be coated with a corrosion protective system.

All interior and exterior deck spaces shall be coated with a high quality non-slip coating.

Craft bottom surfaces, plenum interior surfaces, and the craft sides below the main deck, shall be coated with a high quality low friction epoxy system such as International Inerta 160 or equivalent. The purpose of this is to reduce ice accretion on surfaces subject to spray and provide a high durability coating in areas subject to abrasion.

Other areas, such as bulkheads and deckheads, shall be painted with good quality marine paint suitable for the application.

5.8 HULL EQUIPMENT

5.8.1 Safety Rail

A removable safety rail shall be fitted around the outer edge of the craft main deck.

5.8.2 Access Ladders

An access ladder shall be provided for access to and from the host ship as shall a ladder for access to and from the ground or shore.

5.8.3 Plenum Walkway and Air Lock

A walkway shall be provided around the inside of the plenum above the main skirts. A double door air lock shall be provided for access to this walkway.

5.8.4 Pushing Point

A pushing point of suitable strength for the estimated pushing loads and adjustable for the bow forms of expected pushing vessels shall be fitted at the stern of the craft. The structure of the pushing point should restrain relative motions in the horizontal plane while allowing relative motions in the vertical plane.

5.9 SAFETY EQUIPMENT

The following safety equipment shall be fitted where indicated:

- o Three (3) life rings located on the rail;
- o Six (6) fire extinguishers in the control and machinery rooms and on deck;
- o One (1) first aid kit located in the control room;
- o An integrated firefighting system as defined in Section 5.16

5.10 MAIN MACHINERY AND SYSTEMS

5.10.1 General

The main engines shall be two (2) diesel engines, each driving a forced draft fan via an electromagnetic clutch and a 300 kW synchronized generator via a belt drive. A 100 kW auxiliary generator (battery started) shall also be installed. Two (2) ballast pumps shall be connected to a 5-tank, 90 tonne capacity ballast system. Engine cooling water heat extraction shall be provided by, main engine manufacturer supplied, independent air cooled radiator modules to be located on deck. An integrated bilge and fuel oil sludge holding tank system with two hand pumps shall be installed; as will a fuel system consisting of a single 9 tonne holding tank, one (1) ½ tonne auxiliary generator tank, two (2) oil purifiers and a hand pump. A main engine air start system shall also be fitted consisting of two (2) air compressors, two (2) air purification systems, and two (2) air receiver bottles of 0.56 m^3 for 150 psi air. Two (2) transit winches of 8 tonne tension and one attachment winch of 20 tonne tension shall be provided as will a 4-leg hydraulic lifting system, lifting over a distance of 2.1 m with a 100 tonne/leg capacity.

5.10.2 Main Engines, Fans and Generators

The main engines shall consist of two (2) Detroit Diesel Allison 16V-149-TI, or equivalent, diesel engines of 1500 HP @ 1800 RPM. They shall be air start and each engine shall have independent engine driven auxiliaries, e.g. fuel pump, cooling water circulation pumps, etc. Cold air start capability will also be provided as will air manifold heating. Auxiliary system heaters with a "switch off" mode will be fitted for both block/jacket and line installation. To ensure engine cooling is independent of hover condition, thermostatically controlled engine cooling water air cooled heat exchange modules located on deck will be provided.

Each engine will, through an electromagnetic clutch, drive a Howden M3-6000 or equivalent, forced draft fan at 1800 RPM with 821 shaft horsepower having 80% static efficiency or higher thereby providing lift air. The fans shall be single width, backward inclined airfoil bladed, single open inlet, constant speed variable inlet vaned type.

Each engine shall also power a 300 kW synchronized 600 V, 3 ph, 60 Hz generator via a belt drive, to provide normal operation electrical power.

Monitoring control and alarms, etc. shall be provided by the engine manufacturer and have local engine position, with remote control room and ship bridge control installations.

5.10.3 Auxiliary Generator

The auxiliary generator shall be a Detroit Diesel Allison 71T series, 100 kW, 600 V, 3 ph, 60 Hz non-synchronized generator, or equivalent. It shall be battery started, have cold air start capability and have independent auxiliary system and heating as per the main engines.

5.10.4 Hydraulic Lifting System

A 4-leg hydraulic lifting system shall be installed to lift 2.1 m with a 100 tonne capacity per leg, legs flush to the base when retracted. The system to have electric hydraulic oil heaters with "switch off" capability.

5.10.5 Fuel Oil System

No. 2 diesel fuel oil tanks, emergency and main tank, shall be fitted having sufficient capacity for the required 12-hour operational period. Major components of the fuel oil system are:

- Two (2) Alfa Laval fuel oil purifiers, MAB104's, or equivalent.
- One (1) hand fuel transfer pump with nitrite diaphragms.
- One (1) 9 tonne holding tank with heater.
- One (1) 0.5 tonne emergency holding tank with heater.

Piping lines equipped with valves and filters shall deliver fuel to the interface connections with the main engines and auxiliary generator. Fuel Oil System Diagrammatic No. 1-7113-201.

5.10.6 Cooling System

The water cooling system shall be independent for each engine and comprise the following equipments:

- Engine mounted pumps, piping, valves, etc.

- Thermostatically controlled deck mounted, air cooled radiator module to ensure cooling independent of hover condition with two (2) "built-in" 7½ HP cooling fans.

- The auxiliary generator radiator module shall be low noise (68-72 dB) and have one (1) cooling fan.

Water Cooling System Diagrammatic No. 1-7113-203.

5.11 BALLAST SYSTEM

The ballast system shall comprise the following equipments:

- Five (5) ballast holding tanks of 90 tonnes total capacity;
- Two (2) Hamworthy Serial B200, or equivalent, 15 kW electrical ballast pumps with a total system crash discharge time of 15 minutes.

Piping lines equipped with valves for cross-pumping, suction and discharge shall be fitted. The sea suction shall be via a portable semi-rigid rubber suction pipe.

Ballast System Diagrammatic No. 1-7113-202.

5.12 BILGE SYSTEM

The bilge system shall comprise the following:

- One (1) 3 tonne F.O. sludge and bilge tank;
- Two (2) hand transfer pumps with nitrite diaphragms;
- Each machinery space shall have two bilge suction points.

Discharge shall be via deck connection points to a reception facility, each point shall have a 0.08 m^3 saveall.

Bilge System Diagrammatic No. 1-7113-204.

5.13 AIR SYSTEM

The air system shall comprise the following:

- Two (2) Hamworthy 3TM30 air cooled 150 psi, 1500 RPM, 15 kW, or equivalent, air compressors.

- Two (2) Pall air purification systems Model 10HA44000GJS, or equivalent, one per receiver.
- Two (2) 0.56 m^3 air receivers with capacity for six (6) 16 sec. starts.

The purification system shall have prefilter, auto drain trap, heaterless dryer, after filter and control shutdown features.

5.14 SHIP SERVICE ELECTRICAL

5.14.1 General

The ship shall be equipped with a 600 V, and 115 V, 3 ph, 60 Hz 4-wire system. Reference should be made to G&M Drawing No. 1-7113-301, Single Line Diagrammatic accompanying this design.

5.14.2 Cables

Shall be cross-linked polyethylene insulated PVC, jacketed alpha sheathed having passed the cold bend impact and fire standard tests and being suitable for marine applications.

5.14.3 Lighting

Lighting shall consist of:

- Running lights - (i) Mast light
  (ii) Towing lights
  (iii) N.U.C. lights
  (iv) Anchor lights
- Compartment lights
- Deck floodlights

5.14.4 Communication System

A hard wire from ACIB to bridge, communication system shall be fitted with jacks in each machinery space, winch station, and in the control room.

5.15 CONTROL SYSTEM

The control system shall be provided for ship bridge and control room remote control and consist of:

- o Guide vane controls
- o Winch hydraulic control panel
- o Main engine start/stop and operating controls
- o Auxiliary generator start/stop and operating controls
- o Cushion pressure gauge and fore end hover height gauge
- o Fuel level warning
- o Firefighting operation controls
- o Alarms - main engine, generator and auxiliary machines
- o F.O. sludge and bilge tank remote operated discharge valve and audio/visual warning
- o F.O. main and emergency tank high and low level alarms and remote control valve
- o Ballast operational controls

5.16 FIREFIGHTING SYSTEM

The firefighting system shall consist of the following:

- o Fire monitor system
- o Remote and local operated Halon flooding for the machinery spaces
- o Remote and local operated CO_2 sump flooding system for the main engine and auxiliary generator
- o Smoke detectors in the control room and each machinery space
- o Repeater fire monitor system to the bridge

5.17 WINCHES

The following winches will be provided:

- o Two (2) 8 tonne tension electrical transit winches;
- o One (1) 20 tonne tension electrical attachment winch.

Brakes and load limiting devices to prevent cable tension under steady operating conditions exceeding ½ cable breaking strain will be fitted.

5.18 MISCELLANEOUS

The following items will also be provided:

- Four (4) clear view screens for control room, Kent or equivalent.
- Machinery space stores and control room space heaters.
- Ballast heaters.
- Fuel oil tank heaters.
- Auxiliary systems line and block/sump heaters.
- Hydraulic oil heaters.
- A chemical toilet.
- A Panasonic auto Iris control underwater camera for skirt condition monitoring plus a 9" monitor.
- A compressed air reduction valve from 150 psi/40 psi for air tool connection.
- 115V conv. outlets in the control room and machinery spaces.

5.19 SKIRT SYSTEM

5.19.1 Main Skirts

The main skirt system shall consist of sixty (60) single piece finger skirts equally spaced around the craft perimeter. The skirt pitch at the outer edge will be approximately 1.24 m. The skirts will be constructed of an elastomer covered fabric capable of withstanding the design pressure without significant (> 10%) distortion in any dimension. (Uniroyal PN200 fabric or equivalent). Finger skirts will be continuously mounted along the skirt top edge to rails which can be slid on and off tracks attached to the craft bottom. Outside sealing shall be achieved with a flap and metal sealing plate which when secured also holds the skirt rails in place.

5.19.2 Drag Sheets

Scooping by rear finger skirt segments will be prevented by separate drag sheets which shall be hung on the inside of the finger skirts in such a way that they cover the lower portion of the skirt opening. Each drag sheet shall cover three finger skirts and shall be installed over all skirts aft of the craft mid-section.

5.19.3 Spray Skirt

A two-piece spray skirt shall be installed all around the craft. The inner skirt shall be suspended by chains to allow air escape at the top and extend from 2.5 m above the craft baseline to 1.5 m below the craft baseline. The outer skirt shall be suspended directly above the inner skirt suspension chains and shall cover the gap left by the chains and extend a further 0.5 m over the inner spray skirt. The spray skirts and drag sheets shall be of a material similar to the main skirts.

In all cases, refer to the General Arrangement Drawing No. 1-7113-101 for skirt system layout.

6.0 MID-ARCTIC ACIB

The development of an air cushion icebreaker for 2 m ice thicknesses presents a number of technological challenges. This capacity is beyond any operating experience gained to date and requires cushion pressures greatly in excess of those required for any current hovercraft design. The high pressure and consequent high specific weight of the craft present serious problems in the areas of craft stability, skirt material deformation and lift powering. These problems have led to the consideration of a fairly radical and definitely untried concept, this being a rigid sidewall craft with flexible skirts only at the fore and aft ends.

The rigid sidewall Mid-Arctic ACIB concept was developed in response to the basic problems of craft stability and high cushion pressure. The partial immersion of the sidewall offers some improvement in craft stability due to hydrostatic forces on the structure. The solid sides are also better able to contain the high cushion pressure and clearly will not distort. Air leakage is considerably reduced allowing the installation of less lift power and maintenance on the rigid skirt sections would be negligible compared to that for flexible skirts.

It is clear at this stage that questions remain to be answered before the rigid sidewall design can be taken beyond the concept stage. The most obvious and serious of these being the interaction between the sidewalls and the ice. This is discussed in more detail in Section 6.5.

The rigid sidewall design has been developed and presented for two reasons. It is felt that a 2 m capable soft cushion craft could be reasonably extrapolated from the Inland Waters ACIB. This would involve an increase in size and a considerable increase in power and ballast capacity but these are considered to be possible. The rigid sidewall craft offers a novel and promising concept rather than an extension of the smaller concept.

Secondly, the rigid sidewall is felt to be deserving of serious investigation as it offers many advantages for operation in heavy ice. Only through further research can it be determined if the craft can be practically realized and the concept presented gives a good starting point for further investigation.

The following sections detail the individual aspects of the concept design.

6.1 PLANFORM AND LAYOUT

The rigid sidewall concept dictates a primarily rectangular planform. This is not the optimum shape for air cushion icebreaking but it is likely that the forward edges of the sidewalls will cut the leading edge of the ice sheet, leading to failure more in keeping with two dimensional theory than the three dimensional or cusped breaking pattern predicted and observed for soft cushion craft. For the two dimensional or cantilevered breaking pattern, the rectangular planform offers a better shape for icebreaking. To aid this cutting action, the leading edge of the sidewall has been carried forward of the flexible skirts at a low stem angle. In addition, the sidewall profile is tapered towards the bottom to provide a sharper edge.

Ballast is carried in the double bottom to keep the centre of gravity low. Main and auxiliary equipment is mounted as low as possible, and a machinery enclosure is provided for all equipment including winches. This offers a high degree of environmental protection allowing operations and maintenance to proceed in any weather.

No attempt has been made to provide open deck space for off-season load carrying as this is not foreseen as a potential use for a rigid sidewall ACIB.

A notch is not included in the design for the same reasons detailed in the section concerning the Inland Waters ACIB.

Similarly to the smaller ACIB, an elevated control room with a full view of the craft is provided.

6.2 SKIRT CONFIGURATION

The requirement for straight skirt runs across the front and rear of the craft makes it possible to use a single segment type fore and aft. Scooping at the rear segments shall be prevented with a separate, full width drag sheet. The high specific weight of the craft precludes arranging the skirts for convenient over-water maintenance and this would probably be best achieved with the craft beached. The skirts shall be mounted on continuous rails for ease of removal and to provide distributed support for the highly stressed skirt material. As with the smaller craft a simple, knuckleless skirt design is employed fore and aft to improve handling and reduce complexity.

Because of the high cushion pressures the skirt segments may have to be specially moulded in order that the reinforcing threads can be oriented in the direction of the principal stresses. Without this, the skirt material would suffer excessive distortion and probably failure along the weave diagonal. This is an area in which some research and development is required before a detail design of a skirt system for a craft of this capability can proceed.

6.3 POWERING AND AIR DELIVERY

Lift power is provided by four (4) diesel engines driving centrifugal fans. The engines are all the same size and able to maintain hover in the event of a failure of one engine.

Air feed to the cushion is through two plenums above the front and rear skirts respectively. Two (2) fans feed each of the forward and after plenums. Plenum air velocities are kept low to minimize duct losses.

Electric power is provided by two main generators driven by separate diesel engines. An auxiliary generator set supplies power when the main generators are not operating and all craft systems and machinery are electric to allow a single power system and reduce maintenance.

6.4 BALLAST SYSTEM

All-up weight and trim adjustment is achieved through the use of a liquid ballast system employing water as the ballast medium. Electric heat is supplied to prevent freezing and the ballast tanks are insulated to reduce energy consumption to reasonable levels.

This system offers increased flexibility, control and safety compared to a solid ballast system. The use of heated water reduces the possibility of pollution in the case of an emergency requiring the disposal of ballast.

The system shall be provided with a means of evacuating the tanks quickly for emergencies and to enable the tanks to be drained at the end of each working session.

6.5 SIDEWALL/ICE INTERACTION

Consideration has been given to the effect sidewall/ice interaction will have on net cushion pressure. It is predicted that if the forward edges of the sidewalls do encounter solid ice, the resulting load transfer from cushion to sidewall will result in a loss of effective cushion pressure. To compensate for this effect, it may be necessary to operate a rigid sidewall ACIB at considerable over-pressures. This would mean that the cushion pressure measured in centimeters of water would have to be much higher than the ice thickness.

Preliminary calculations indicate that this over-pressure may have to be as much as 40%. The introduction of over-pressure would also be

beneficial in that it would encourage the cushion bubble to travel ahead of the craft, thus inducing failure before the sidewalls met the sheet. The major drawbacks of the extra pressure requirements would be increased craft weight and substantially higher power requirements.

Because this effect has not been adequately studied or proven, the Mid-Arctic ACIB concept has been designed for 2 m of ice without considering any degree of over-pressure. Before the concept is carried any further, some work should be done to determine whether or not over-pressure is required and if it is, will the added power and weight neutralize the benefits of the rigid sidewall.

7.0 MID-ARCTIC ACIB DESIGN SPECIFICATION

7.1 GENERAL

Similarly to the Inland Waters ACIB, this specification and drawing package presents a concept design for a Mid-Arctic ACIB. The package is intended to identify the major components and their arrangement to establish the feasibility of the design and support a cost estimate. Some elements of this specification are similar to corresponding sections for the Inland Waters craft. In cases where this is so, the corresponding section will be referred to rather than repeated.

The specification is divided into hull, machinery and skirt system sections. The following drawings and diagrammatics are illustrative of the concepts and support of the specification:

	G&M DWG. No.
o General Arrangement	1-7113-111
o Structural Arrangement & Sections	1-7113-112
o Fuel Oil System Diagrammatic	1-7113-211
o Ballast System Diagrammatic	1-7113-202
o Engine Cooling System Diagrammatic	1-7113-213
o Bilge System Diagrammatic	1-7113-214
o Electrical System Single Line Diagram	1-7113-311

Systems are detailed in the following sections. In all cases, the craft has been designed to meet the performance specification (Section 3.0).

7.2 HULL SPECIFICATION

7.2.1 Principal Particulars

The Mid-Arctic ACIB shall be a rectangular planform, rigid sidewall air cushion craft with the following principal particulars:

o Length	27 m
o Width	32 m

o	Depth to main deck	6 m
o	Bottom clearance (on hover)	2.0 m (min.)
o	Maximum cushion pressure	20 kPA
o	Maximum all-up weight	1200 tonnes

7.2.2 General Arrangement

The design General Arrangement is presented on G&M Drawing No. 1-7113-111.

7.2.3 Design Standards

The craft has been designed in accordance with the Canadian Department of Transportation Guide to Certification Requirements for Non-Self-Propelled Air Cushion Vehicles. Structural design is in accordance with Lloyd's Rules for Building and Classing Steel Ships. The sidewalls from the main deck down have been designed in accordance with ASPPR Arctic Class 1.

7.3 HULL STRUCTURE

7.3.1 Materials

See Inland Waters ACIB, Section 5.3.1.

7.3.2 Hull and Superstructure

The hull and superstructure structural arrangement is detailed on G&M Drawing No. 1-7113-112.

7.4 OUTFIT AND FURNISHINGS

See Inland Waters ACIB, Section 5.4.

7.4 DOORS, HATCHES AND WINDOWS

All doors are to be of accepted marine standards and shall be located where indicated on the General Arrangement drawing.

A pair of large doors shall be fitted in the machinery space for access with large parts or equipment.

The control room windows shall be fixed except for two opening windows. All windows are to be safety glass. Electric motor driven clear view screens shall be fitted, one in the centre of each side of the control room.

7.6 INSULATION

See Inland Waters ACIB, Section 5.6.

7.7 PAINT AND SURFACE COATINGS

See Inland Waters ACIB, Section 5.7.

7.8 HULL EQUIPMENT

See Inland Waters ACIB, Section 5.8.

7.9 SAFETY EQUIPMENT

See Inland Waters ACIB, Section 5.9.

7.10 MAIN MACHINERY AND SYSTEMS

7.10.1 General

The main engines will be four (4) diesel engines, each driving a forced draft fan via an electromagnetic clutch; there will also be two (2) diesel engines each driving a 300 kW non-synchronized generator. A 50 kW auxiliary generator (battery started) shall also be installed. Two (2) ballast pumps shall be connected to a 4-tank, 600 tonne capacity ballast system. Engine cooling water heat extraction shall be provided by, main engine manufacturer supplied, independent air cooled radiator modules to be located on deck. An integrated bilge and fuel oil sludge holding tank system with two electrical driven pumps shall be installed; as will a fuel system consisting of two (2) holding tanks each of 20 tonne capacity and one (1) 3 tonne emergency tank, two (2) oil purifiers and a electrical driven transfer pump. A main engine and generator air start system shall also be fitted consisting of two (2) air compressors, two (2) air purification systems, and two (2) air receiver bottles of 1.40 m^3 for 150 psi air. Two (2) transit winches of 10 tonne tension and one (1) attachment winch of 25 tonne tension shall be provided.

7.10.2 Main Engines, Fans and Generators

The main engines shall consist of four (4) Detroit Diesel Allison 16V-149-TIB, or equivalent, diesel engines of 1700 HP @ 1800 RPM. They shall be air start and each engine shall have independent engine driven auxiliaries, e.g. fuel pump, cooling water circulation pumps, etc. Cold air start capability will also be provided as will air manifold heating. Auxiliary system heaters with a "switch off" mode will be fitted for both block/jacket and line installation. To ensure engine cooling is independent of hover condition, thermostatically controlled engine cooling water air cooled heat exchange modules located on deck will be provided.

Each engine will, through an electromagnetic clutch, drive a Howden M3-6300 or equivalent, forced draft fan at 1800 RPM with 1360 shaft horsepower having 85% static efficiency or higher thereby providing lift air. The fans shall be single width, backward inclined airfoil bladed, single open inlet, constant speed variable inlet vaned type.

Two (2) Detroit Diesel Allison 71T series, or equivalent, diesel engines shall each power a 300 kW non-synchronized 600 V, 3 ph, 60 Hz generator to provide normal operation electrical power. They shall be air start with auxiliaries and support systems as per the main engines.

Monitoring control and alarms, etc. shall be provided by the engine manufacturer and have local engine position, with remote control room and ship bridge control installations.

7.10.3 Auxiliary Generator

The auxiliary generator shall be a Detroit Diesel Allison 71 series, 50 kW, 600 V, 3 ph, 60 Hz non-synchronized generator, or equivalent. It shall be battery started, have cold air start capability and have independent auxiliary system and heating as per the main engines.

7.11 FUEL OIL SYSTEM

No. 2 diesel fuel oil tanks, emergency and main tank, shall be fitted having sufficient capacity for the required 24-hour operational period. Major components of the fuel oil system are:

- Two (2) Alfa Laval fuel oil purifiers, Type MAB204, or equivalent.
- One (1) electrical driven fuel transfer pump, Hamworthy Type SNH-210 R46, or equivalent.

- Two (2) 20 tonne holding tanks with heaters.

- One (1) 3 tonne emergency holding tank with heater.

Piping lines equipped with valves and filters shall deliver fuel to the interface connections with the main engines and auxiliary generator. Fuel Oil System Diagrammatic No. 1-7113-211.

7.12 COOLING SYSTEM

The water cooling system shall be independent for each engine and comprise the following equipments:

- Engine mounted pumps, piping, valves, etc.

- Thermostatically controlled deck mounted, air cooled radiator module to ensure cooling independent of hover condition with two (2) "built-in" 10 HP cooling fans for main engines and two (2) 8 HP cooling fans for the generators.

- The auxiliary generator radiator module shall be low noise (68-72dB) and have one (1) cooling fan of 2 HP.

Water Cooling System Diagrammatic No. 1-7113-213.

7.13 BALLAST SYSTEM

The ballast system shall comprise the following equipments:

- Four (4) ballast holding tanks of 150 tonnes capacity each;

- Two (2) Hamworthy Serial B8x6VP, or equivalent, 31 kW electrical ballast pumps with a total system crash discharge time of 40 minutes.

Piping lines equipped with valves for cross-pumping, suction and discharge shall be fitted. The sea suction shall be via a portable semi-rigid rubber suction pipe.

Ballast System Diagrammatic No. 1-7113-202.

7.14 BILGE SYSTEM

The bilge system shall comprise the following:

- One (1) 10 tonne F.O. sludge and bilge tank;
- Two (2) electrical driven transfer pumps, Hamworthy Type 34460 Horizontal progressive cavity pump, or equivalent;
- The machinery space shall have four bilge suction points.

Discharge shall be via deck connection points to a reception facility, each point shall have a 0.08 m^3 saveall.

Bilge System Diagrammatic No. 1-7113-214.

7.15 AIR SYSTEM

The air system shall comprise the following:

- Two (2) Hamworthy 2LT20A air cooled 150 psi, 1500 RPM, 6 kW each, or equivalent, air compressors.
- Two (2) Pall air purification systems Model 15HA44000GJS, or equivalent, one per receiver.
- Two (2) 1.40 m^3 air receivers with capacity for six (6) 16 sec. starts.

- o A reduction valve to 40 psi for air tool connection.

The purification system shall have prefilter, auto drain trap, heaterless dryer, after filter and a control shutdown features.

7.16 SHIP SERVICE ELECTRICAL

7.16.1 General

The ship shall be equipped with a 600 V and 115 V, 3 ph, 60 Hz 4-wire system. Reference should be made to G&M Drawing No. 1-7113-311, Single Line Diagrammatic accompanying this design.

7.16.2 Cables

Shall be cross-linked polyethylene insulated PVC, jacketed alpha sheathed having passed the cold bend impact and fire standard tests and being suitable for marine applications.

7.16.3 Lighting

Lighting shall consist of:

- o Running lights - (i) Mast light
  (ii) Towing lights
  (iii) N.U.C. lights
  (iv) Anchor lights
- o Compartment lights
- o Deck floodlights

7.17 COMMUNICATION SYSTEM

A hard wire from ACIB to bridge, communication system shall be fitted with jacks in each machinery space, winch station, and in the control room.

7.18 CONTROL SYSTEM

The control system shall be provided for ship bridge and control room remote control and consist of:

- o Guide vane controls
- o Winch hydraulic control panel
- o Main engine start/stop and operating controls
- o Generator start/stop and operating controls
- o Auxiliary generator start/stop and operating controls
- o Cushion pressure gauge and fore end hover height gauge
- o Fuel level warning
- o Firefighting operation controls
- o Alarms - main engine, generator and auxiliary machines
- o F.O. transfer pump operating controls
- o F.O. sludge and bilge tank remote operated discharge valve and audio/visual warning
- o F.O. main and emergency tank high and low level alarms and remote control valve
- o Ballast operational controls
- o Bilge pumps operating controls

7.19 FIREFIGHTING SYSTEM

The firefighting system shall consist of the following:

- o Fire monitor system
- o Remote and local operated Halon flooding for the machinery space
- o Remote and local operated CO_2 sump flooding system for the main engine, generators, and auxiliary generator
- o Smoke detectors in the control room and each machinery space
- o Repeater fire monitor system to the bridge

7.20 WINCHES

The following winches will be provided:

- Two (2) 10 tonne tension electrical transit winches
- One (1) 25 tonne tension electrical attachment winch

Brakes and load limiting devices to prevent cable tension under steady operating conditions exceeding ½ cable breaking strain will be fitted.

7.21 MISCELLANEOUS

The following items will also be provided:

- Four (4) clear view screens for control room, Kent or equivalent.
- Machinery space stores and control room space heaters.
- Ballast heaters.
- Fuel oil tank heaters.
- Auxiliary systems line and block/sump heaters.
- A chemical toilet.
- A Panasonic auto Iris control underwater camera for skirt condition monitoring plus a 9" monitor.
- 115V conv. outlets in the control room and machinery space.

NOTE: System diagrammatics presented in this design allow the major components of the system to be indicated. The diagrammatics are illustrative and should not be considered unchangeable.

7.22 SKIRT SYSTEM

7.22.1 Main Skirt

The main skirt system shall consist of a forward and after row of single piece finger skirts arranged as shown on the General Arrangement Drawing No. 1-7113-111. The skirt pitch at both ends shall be approximately 1 m. The main skirts shall be constructed of

an elastomer covered fabric capable of withstanding the design pressure without significant (>10%) distortion in any dimension. The finger skirts will be continuously mounted along the skirt top edge to rails which can be slid on and off tracks attached to the craft bottom. Sealing shall be achieved with a flap and metal sealing plate which shall also serve to secure the skirt rails.

7.22.2 Drag Sheet

Scooping by rear finger skirt segments will be prevented by a single piece full width drag sheet. The drag sheet shall be suspended ahead of the rear skirt segments in such a way as to prevent material from entering the bottom of the skirt while allowing air to flow over the top of the drag sheet.

7.22.3 Spray Skirts

Two piece, full width spray skirts shall be fitted outside the forward and aft main skirts. The inner skirt shall be suspended by chains to allow air escape at the top and the skirt shall extend from the craft bottom to a point 0.5 m above the bottom of the fully inflated main skirts. The outer skirt shall be suspended directly from the main skirt suspension point and shall cover the gap left by the chains and extend a further 0.8 m over the inner skirt.

7.22.4 Materials

It is presently unclear whether or not currently available elastomer coated fabrics are suitable for main skirt construction at the design pressures considered for the Mid-Arctic ACIB. It is possible that a specially woven or moulded skirt may have to be considered. For the purposes of this specification, Uniroyal PN200 fabric or equivalent, is specified for use in all skirt locations.

For skirt system arrangement, refer to G&M Drawing No. 1-7113-211.

8.0 CONSTRUCTION AND LIFE CYCLE COSTS

8.1 CONSTRUCTION COSTS

Capital costs for the two ACIBs were estimated on the following basis. Major equipment items were specified and quotes solicited from Canadian manufacturers where possible. Minor machinery and equipment costs were estimated based on similar equipment specified for previous designs undertaken by German & Milne. Installation costs were estimated based on data and experience acquired from previous ship designs.

Steel and fabrication costs were estimated based on current Eastern Canadian shipyard rates. Steel weight was broken down by weight of plating and rolled sections and costed on an average cost per tonne and man-hours per tonne for each component. Labour rates were taken to be thirty dollars per man-hour overhead and profit included. In all cases, costs are quoted in current (mid-1984) dollars. Costs for coatings and insulation are based on manufacturers quotes and shipyard based application times.

Major electrical equipment was estimated based on manufacturers' quotes. Cost of wiring was estimated on an installed cost per foot basis.

The skirt system costing was based on recent supplier estimates based on experience with the CCG ACIB skirt system. The skirt system cost includes main skirts, drag sheets, spray skirts, attaching hardware and installation on the craft.

It should be noted that the cost for the Mid-Arctic ACIB skirt system assumes that the same material specified for the Inland Waters craft will be suitable for the higher pressure. No attempt has been made to cost a specially moulded system which may be required for the high pressure application.

The estimated construction costs presented represent the expected acquisition costs for the two ACIB concepts presented in this report.

The margin for error is likely to be plus or minus 15% for an estimates of this type but the cost is judged to give a fair indication of the expected cost of the two machines.

The total construction cost for the Inland Waters ACIB as presented in this design is estimated to be $3,162,000 Canadian.

The total construction cost for the Mid-Arctic ACIB as presented in this design is estimated to be $7,092,000 Canadian.

For a breakdown of the cost by major craft system, see Appendix 3.

8.2 LIFE CYCLE COSTS

Life cycle costs for the ACIBs were somewhat difficult to estimate. There has been little experience with ACIB operations and that which has been gained has been on a craft with an extremely chequered history. With this in mind, efforts were made to estimate life times, maintenance intervals and repair costs based on experiences with the CCG ACIB and normal marine practice.

The life cycle costing is based on operational scenarios developed for the craft. Two scenarios were developed for the Inland Waters ACIB and a single one for the Mid-Arctic ACIB. The two operational profiles developed for the Inland Waters ACIB reflect the two modes of operation identified in the first phase of the study. The first profile is typical of operations in a single harbour area such as are presently carried out in Thunder Bay. The second profile is typical of ice management operations over a wider area and longer season. An example of this type of operation would be the maintenance of winter navigation in and out of Lake Melville.

A single operational scenario was developed for the Mid-Arctic ACIB to cover the escort and anchorage clearance activities during the Northern winter seson. The three operational scenarios are explained in more detail in a later section.

For each scenario, the length of the operating season was predicted as was the expected number of actual operating hours. An engine power profile was estimated and combined with the operating time prediction to give average annual fuel and machinery maintenance cost. Yearly mothballing and pre-season preparation costs were also estimated. For all cases, it is expected that the ACIB will require three crew members and this is the only direct labour cost associated with the operation. It is expected that this crew or a similar number of people will be available for pre- and post-season maintenance.

The skirt system is expected to be the major item requiring maintenance. For this system, a mean time between major skirt repairs has been estimated. This is based on experience with the CCG ACIB taking into account the improved design of the concept design skirt system. Average cost of repairs is based on the replacement cost of a single main skirt segment.

Long term items such as skirt system replacement, major machinery overhaul, and hull refit were assigned time intervals and costs based on estimated severity of service. Costs were estimated from the capital cost estimate prepared initially.

Costs are estimated and presented on a yearly basis. In no case are the effects of inflation accounted for and all figures are in current (mid-1984) dollars. For calculation of net present value and yearly capital recovery value, a discount rate of 10% is used. The yearly capital recovery value indicates the average yearly economic benefit over the life of the craft which would have to be derived from the use of the ACIB in the predicted mode in order to recover the total costs involved in acquisition and maintenance.

Operating scenarios and predicted costs, including net present value and capital recovery value, are presented in the following sections.

8.2.1 Inland Waters ACIB Harbour Operations

This is a light duty operational cycle involving port ice management over a period of one month each year. Added to this is a month for craft preparation and another month to ready the craft for storage. The operational season would thus be approximately three months long with a nine month storage period. Shore facilities required for this type of service would consist of a concrete beaching pad and an indoor area for the off season storage of skirts. Under this type of operation, total craft life is estimated to be 25 years.

- **Lead time - 1 month:**

Engine and machinery preparation	30 man-days
Skirt system installation	15 man-days
General hull preparations	12 man-days
Total Labour	57 man-days

Materials for seasonal maintenance: $5,000.00

- **Operational Time - 1 month or 25 days @ 8 hrs/day:**

Three-man crew, 75 man-days

Expected power profile: 35% of time @ 70% power,
35% of time @ 85% power,
30% of time @ 100% power.

Average fuel consumption - 460 kg/hr.

Total fuel consumption: 92 tonnes plus 10 t for aux.
Total = 102 tonnes @ $446.60/tonne
= $45,500.00 yearly fuel cost.

Estimated mean time between major skirt damage: 100 hrs.

Average cost of repairs: $5,000.00

- **Follow-Up Time - 1 month:**

Engine and machinery prep for storage	30 man-days
Skirt system removal	15 man-days
Decommission craft	20 man-days
Total Labour	**65** man-days

Preservation, cleaning, touch-up materials: $6,000.00

- **Total Annual Costs:**

Labour - 197 man-days @ $320/day	$63,040.00
Fuel	45,500.00
Skirt repairs	10,000.00
Misc. materials	11,000.00
Total	**$129,540.00**
Rounded	$130,000.00

- **Long-Term Maintenance Intervals and Cost:**

Expected craft life	25 yrs	
Skirt system replacement	5 yrs	$400,000.00
Major engine refit	10 yrs	100,000.00
Minor hull repaint	5 yrs	100,000.00
Major hull repaint	10 yrs	500,000.00

- **Cost Breakdown:**

Capital cost	$3,162,000.
Annual cost	130,000.
Years 5 & 15	500,000.
Years 10 & 20	1,000,000.
Life end scrap value	100,000.
Total net present value	**$5,297,000.00**
Capital Recovery Value (per year for 25 years)	**$ 583,500.00**

8.2.2 Inland Waters ACIB Sea Lane Operations

This is a heavy duty operational cycle involving ice management both in a port area and along a moderately long (50 mile) sea lane over a period of seven months with a month each for pre- and post-season preparation. Shore facilities would consist of a concrete landing pad and an enclosed area for skirt storage and maintenance. Under this type of operation, the craft life is estimated to be 20 years.

- **Lead Time - 1 month:**

Engine and machinery preparation	30 man-days
Skirt system installation	15 man-days
General hull preparations	12 man-days
Total Labour	57 man-days

Materials for seasonal maintenance: $8,000.00

- **Operational Time - 7 months or 30 weeks @ 40 hrs/week:**

Three-man crew, 450 man-days.

Expected power profile - 25% of time @ 60% power,
30% of time @ 70% power,
20% of time @ 80% power,
10% of time @ 90% power,
10% of time @ 100% power.

Average fuel consumption: 387 kg/hr.

Total fuel consumption - 470 tonnes plus 20 t for aux.
Total = 490 t @ $446.60/tonne
= $218,830.00 yearly fuel cost.

Engine maintenance interval - 500 hrs.
Cost - $3,000.00
Labour - 2 man-days.

Estimated mean time between major skirt damage:	100 hrs.
Average cost of repair:	$5,000.00

- **Follow-Up Time - 1 month:**

Engine and machinery prep for storage:	30 man-days
Skirt system removal:	15 man-days
Decommission craft:	20 man-days
Total Labour	65 man-days
Preservation, cleaning, touch-up materials:	$10,000.00

- **Total Annual Costs:**

Labour - 577 man-days @ $320/day	$184,640.00
Fuel	218,830.00
Skirt repairs	60,000.00
Misc. materials	24,000.00
Total	**$487,470.00**
Rounded	$490,000.00

- **Long-Term Maintenance Intervals and Cost:**

Expected craft life	20 yrs	
Skirt system replacement	5 yrs	$400,000.
Major engine refit	5 yrs	100,000.
Minor hull repaint	5 yrs	100,000.
Major hull repaint	10 yrs	500,000.

- **Cost Breakdown:**

Capital Cost	$3,162,000.
Annual Cost	490,000.
Years 5 & 15	600,000.
Year 10	1,100,000.
Life end scrap value	100,000.

Total Net Present Value: **$8,259,000.00**

Capital Recovery Value: **$ 970,000.00**
(per year for 20 years)

8.2.3 Mid-Arctic ACIB Northern Operations

This is a heavy duty operational cycle involving ice management on sea lanes and near anchorages in Arctic regions during the winter season. The operational seson would be eight months with a two month overhaul period annually. Shore facilities would consist of shallow water area with a wharf and area for beaching the craft. A storage/operations base building would also be required. Craft life is estimated to be 20 years.

- **Yearly Overhaul:**

Labour	90 man-days
Materials	$20,000.00

- **Operational Time - 8 months or 35 weeks @ 48 hrs/week:**

Three man crew:	630 man-days
Expected power profile:	25% of time @ 60% power, 30% of time @ 70% power, 25% of time @ 80% power, 10% of time @ 90% power, 5% of time @ 100% power.
Average fuel consumption:	955 kg/hr
Total Fuel Consumption -	1610 t plus 30 for aux.
Total =	1640 t @ $446.60/t
=	$732,424.00
Engine maintenance interval:	500 hrs.
Total cost approx.:	$27,000.00
Estimated mean time between major skirt damage:	100 hrs.
Average cost of repair:	$8,000.00

- **Total Annual Costs:**

Labour, 720 man-days @ $320/day	$ 230,400.00
Fuel	732,424.00
Skirt repairs	134,400.00
Misc. materials	47,000.00
Total	**$1,144,224.00**
Rounded	$1,145,000.00

- **Long-Term Maintenance Intervals and Cost:**

Expected craft life	20 yrs	
Skirt system replacement	4 yrs	$350,000.
Major engine refit	5 yrs	200,000.
Minor hull repaint	4 yrs	150,000.
Major hull repaint	8 yrs	800,000.

- **Cost Breakdown:**

Capital Cost	$7,092,000.
Annual Cost	1,145,000.
Years 4 & 12	500,000.
Years 5, 10 & 15	200,000.
Years 8 & 16	1,150,000.
Life end scrap value	200,000.

Total Net Present Value: **$18,347,500.00**

Capital Recovery Value: **$ 2,155,000**
(per year for 20 years)

9.0 CONCLUSIONS AND RECOMMENDATIONS

The designs presented in this report represent in one case a mature concept based on considerable research and experience and, in the other case, a somewhat radical new development in the field of ACIBs. The Inland Waters ACIB concept offers a high degree of operational efficiency, reliability and maintainability in addition to the already proven impressive icebreaking performance. The Mid-Arctic concept provides a starting point for the development of a promising modification to ACIB technology for use in heavy ice.

In the course of design development, a number of questions come to light for which clear answers could not be found. Additionally, the introduction of the rigid sidewall craft raised some new questions.

The major question developing from this study was that of ACIB "notching". The advantages of a cushion notch in terms of overall resistance or improved track clearance have not been satisfactorily demonstrated in either theory or experiment. It is felt that any foreseeable gain resulting from a notch would be outweighed by the high capital cost and increased complexity of the notching operation. There are, however, many opinions which feel that a notch offers advantages in these areas. This is a debate which can only be laid to rest by suitable trials.

The issue of ACIB breaking pattern also came up in connection with the development of an efficient planform. Although theory and observations support the semi-circular edge hypothesis, it would be beneficial to perform tests to confirm the icebreaking pattern under an ACIB.

Introducing the rigid sidewall craft has raised the important issue of ice/sidewall interaction discussed in Section 6.5. This is an area in which some theoretical and experimental work clearly needs to be done before the concept can be developed any further.

In conclusion, it is recommended that the following steps be taken to further the development of ACIB technology in Canada.

1. A series of full-scale trials should be carried out with the CCG ACIB and a suitable vessel to demonstrate whether a notch offers any advantage to the ACIB/ship combination. This would be in keeping with the recommendations of an earlier report by P. Markham entitled "Flow Trajectories About an Air Cushion Icebreaking Bow".

   Concurrently with the notch trials, experiments could be done to determine the icebreaking pattern of the ACIB.

2. A series of model tests should be done to determine if the breaking pattern for model ice matches that observed for full-scale ice. Experience with urea doped ice indicates that successful tests could be performed at 1:16 scale. At this scale, residual flexural strength effects should be negligible, thus allowing representative tests. This would help to establish the validity of ACIB model testing at various scale factors and hopefully allow the development of some baseline data as an aid in future developments.

3. Should the model tests recommended in Part 2 be successful, and assuming that the flexural and/or shearing properties of the ice can be successfully modelled, it is recommended that model tests on a rigid sidewall model, of suitable scale, be conducted. These tests would hopefully demonstrate the effects of ice/sidewall interaction and indicate whether or not the concept is worth pursuing.

If required, more detailed proposals for these tests and trials will be prepared.

APPENDIX 1

USER REQUIREMENTS SURVEY

a. English letter and survey form

b. French letter and survey form

c. List of contacts

d. Replies

german & milne inc.

130 Slater Street, Suite 630
Ottawa, Ontario, Canada K1P 6E2
Telephone: (613) 230-6201 Telex: 053-4499 GERMIL OTT

File: 7113

March 9, 1984

Dear Sir:

The use of Air Cushion Vehicles for icebreaking is a technology under development in Canada. Presently ice is broken with an air cushion craft which can be pushed with a conventional ship, icebreaker or tug. This type of craft is known as an Air Cushion Icebreaking Bow or ACIB.

Air cushion icebreaking can offer a simple, cost-effective solution to the problem of ice management in ports, harbours and waterways. Trials with an ACIB at Thunder Bay have demonstrated that ice, the thickness of which requires a conventional icebreaker to use the ramming mode, can be broken continuously with less power and at very much higher speed. Furthermore, a smaller vessel, such as a tug, can be used for propulsion, the combination being extremely manoeuvrable and economical.

Air cushion icebreaking bows can be tailored to the icebreaking requirement, cushion pressure being related to ice thickness, length to ice strength and beam to the track width required. Bottom structure clearance can cater for ridges up to a point.

German and Milne Inc. has been tasked by the Transportation Development Centre, Transport Canada, to identify the needs of Canadian users for:

a) An inland water or coastal ACIB to overcome ice not exceeding 1 m in thickness, with no or very little ridging. This ACIB would be used in rivers, lakes or harbours, and would be pushed by a commercial tug or other light vessel.

. . ./2

b) A mid-Arctic ACIB to overcome sea ice not exceeding 2 m in thickness, with limited ridging. This ACIB would be used in harbours, inlets and lakes, particularly on the Eastern seaboard, and would be pushed by an ice strengthened commercial vessel or, possibly, a CCG icebreaker.

User needs will suggest requirements from which specifications will be written and, when this has been done, designs will be made in sufficient detail to assess feasibility and permit cost estimates.

Your participation in this project would be of great value and your co-operation will be greatly appreciated. The information required is outlined in the attached questionnaire. On completion of the project, every participant will be sent a summary, which will include a specification, a general arrangement drawing, and a construction cost estimate.

Yours truly,
GERMAN & MILNE INC.

Bruce Colbourne

Encls.

BC/cc

QUESTIONNAIRE - ICEBREAKING REQUIREMENTS

PORT:_____ RESPONDENT:_____

TITLE:_____

1. In what areas is ice cleared at present?

2. Who is responsible for ice clearance?

3. What equipment is used for icebreaking?

4. Is present ice management system satisfactory?
   If answer is no, what improvement is desirable? Please indicate the part that improved icebreaking capability could play.

5. Can you see any economic benifit from improved icebreaking capability. If answer is yes please give an estimate of dollar value.

6. Would Port Authority be interested in the purchase or charter of an ACIB for local ice management?

7. What are dimensions of largest ship using the port?

8. Are tugs available locally which could be used to push an ACIB? Please give names of tugs and owners.

9. Please complete the attached table with average values:

10. Please attach a map of the port showing the limit of ice for each month and the areas in which ridging occurs (indicate average thickness). Use map to indicate any special features or areas which require particular attention, slips and jetties, for example.

APPENDIX 'A'

QUESTIONNAIRE - ICEBREAKING REQUIREMENTS

COMPANY:_____RESPONDENT:_____

TITLE:_____

1. Do you use icebreaking services at present? Yes/No.
   Or, would icebreaking services be benificial ato your operation? Yes/No.

2. Who is responsible for ice clearance?

3. What equipment is used for icebreaking?

4. Is present ice management system satisfactory? Yes/No
   If answer is no, what improvement is desirable? Please indicate the part that improved icebreaking capability could play.

5. Can you see any economic benefit from improved icebreaking capability. If answer is yes please give an estimate of dollar value.

6. Would you be interested in the purchase or charter of an ACIB for local ice management?

7. What are dimensions of your ferry?

8. Are tugs available locally which could be used to push an ACIB? Please give names of tugs and owners.

9. Please complete the attached table with average values for your route.

10. Please attach a map of your route showing the limit of ice for each month and the areas in which ridging occurs (indicate average thickness). Use map to indicate any special features or areas which require particular attention.

QUESTIONNAIRE, Page 2

ENVIRONMENTAL Information

MONTH	Ice Thickness (cm) Av.	Ice Thickness (cm) Max.	Ambient Temp. (°C) Av.	Ambient Temp. (°C) Max.	Wind Velocity (m/s) Av.	Wind Velocity (m/s) Max.	Snowfall (cm)

german & milne inc.

130 Slater Street, Suite 630
Ottawa, Ontario, Canada K1P 6E2
Telephone: (613) 230-6201 Telex: 053-4499 GERMIL OTT

File: 7113

Mars 13, 1984

Cher Monsieur:

Au Canada, le véhicule à coussin d'air utiliser comme brise-glace, en est à une phase de dévelloppement. Actuellement nous utilisons un véchicule à coussin d'air, attacher à la proue d'un brise-glace conventionelle, ou d'un remorqueur. Ce type de véhicule est connue sous le nom de véhicule à coussin d'air de proue, VCAP "Air Cushion Icebreaking Bow, ACIB."

L'utilisation du VCAP comme brise-glace, offre une solution simple et économique, au problème du dégagement des glaces dans les ports et voies maritime. Des essaient d'un véhicules à coussin d'air, à Thunder Bay, on démontrer que les glaces requiérant d'un brise glace conventionelle, plusieurs asault, puissent être brisées d'une façon continue plus rapidement et à moindre puissance grace au VCAP. L'utilisation d'un navire de tonnage inférieur est possible, par exemple, un remorqueur attacher au véhicule à coussin d'air peut être utiliser comme mode propulseur. Cette combinaison étant, trés manoeuvrable et économique

Les VCAP construit sur mesure comme brise-glace utilise les relations, entre la pression interne du coussin d'air, l'épaisseur de la glace, à la longeur et largeur du passage désirer. Les accumulations de glaces peuvent causer des contraintres à l'application, ceci due à la limite de l'accès libre de la jante du véhicule et la hauteur de l'obstacle à franchir.

Le Centre de Développement de Transport Canada, à confier à German & Milne la tâche d'identifier les besoins potentiels, d'utilisateurs Canadien.

a) L'utilisateur intérieur ayant peut d'accumulation des glaces, d'une épaisseur d'un (1) métre au plus. L'utilisation du véhicule serait limiter à l'ouverture des lacs, rivières, et ports. Le mode propulseur du VCAP serait un remorqueur, ou n'importe lequel autre navire commercial léger.

. . . /2

b) L'utilisateur de l'Artique centre, pour briser des glaçes n'èxèdant pas deux (2) mètres d'épaisseur avec peut au sans accumulation des glaces. Le véhicule serait utiliser pour l'ouverture des ports, lacs, et chemins navigable, particuliérement ceux de la côte est. Le mode propulseur serait un navire commercial ou de la guarde côtière capable de naviguer dans les eaux couvertes de glaces.

Les besoins des utilisateurs éventuels suggéreront les spécifications, et le degreé de sofistication requis. Lorsque cela sera fait, des devis seront produit pour l'évaluation des côuts et possibilitées de ces véhicules.

Votre participation à ce proget serais trés apprécier, et nous serais d'une très grande valeur. Le questionnaire ci-inclus, énumère les informations requises. A la fin du proget chaque répondant recevra un raport incluant les devis, specifications, et l'évaluations des côut de construction des véhicules à l'étude.

Veuillez agréer, cher monsieur, mes salutions les plus sincères.

J.B. Santirosi, Ing.

JBS/cc

Encls.

QUESTIONNAIRE - BESOINS EN BRISE-GLACES

Port:_____ **Répondent:**_____

Titre:_____

1. Dans quelle région le dégagement des glaces est il présentement effectuer?

2. Qui en a la responabilitée?

3. Quel équipment est utiliser pous le dégagement des glaces?

4. Le système actuel, est il satisfaisant?
   Si non, quel améliorations y seraient nécéssaires? Veuillez indequer la part que l'augmentation de la capacitée de brises les glaces pourrait jouer.

5. Croyez vous que des bénéfices économique seraient attribuable à l'augmentation de votre capacitée de briser les galces, si oui, donnez un estimé en dollars?

6. Est-ce que les authoritées du port seraient intéresser à l'achat ou la location d'un VCAP pour le dégagement des glaces locale?

7. Quel sont les dimensions du plus gros navire utilisant votre port?

8. Y a til des remorqueurs disponnible localement, qui pourraient être utilisés comme mode propulsuer du VCAP? Veuillez donner le noms des remorqueurs et proprietaires.

9. Veuillez compléter le tableau ci-inclus, avec des valeurs moyennes:

10. Veuillez inclure une carte du port indiquant la limite des glaces pour chaque mois, et les régions au les accumulations se produises (indiquer l'épaisseur moyenne). Utiliser la carte pour indiquer toutes conditions spéciales ou régions requiérant une attention particulière, comme par exemple des jetteés et amares.

QUESTIONNAIRE - BESOINS EN BRISE-GLACES

Compagnie:_____ **Répondent:**_____

Titre:_____

1. Utilisez-vous des services de brise-glace? Qui/Non.
   Ou, des services de brise-glace serait-il benefique pour votre opération? Oui/Non.

2. Qui est responsable du dégagement des glaces?

3. Quel équipment est utiliser à cette fin?

4. Le système utiliser est il satifaisant? Oui/Non, Si Non, quelles améliorations y seraient nécéssaires? Veuillez indiquer la part que l'augmentation de la capacitée de briser les glaces pourrait Y jouer?

5. Croyez vous que des bénéfices économique seraient attribuable à l'augmentation de votre capacitée de briser les glaces, si oui, donnez un estimé en dollars.

6. Seriez-vous in téresser à l'achat ou la location d'un VCAP pour le dégagement des glaces locale?

7. Quels sont les dimensions de votre traversier?

8. Y a til des remorqueurs disponnible localement qui pourraient être utilisés comme mode propulseur du VCAP? Veuillez donner le noms des remorqueurs et proprietaires.

9. Veuillez compléter le tableau ci-inclus avec des valeurs moyenne pour votre route:

10. Veuillez inclure une carte de votre route, indiquant les limites des glaces pour chaque mois, et les régions ou les accumulations se produisent (indiquer L'épaisseur moyenne). Utilisez la carte pour indiquer des conditions spéciales ou régions requiérant une attention particuliére.

Mois	Épaisseur Des Glaces (cm)		Température Environnante		Vélocitée Des Vents (m/s)		Tombée Des Neiges (cm)
	Moyenne	Maximum	Moyenne	Maximum	Moyenne	Maximum	

Mr. Preston Cook,
Port Manager,
Lakehead Harbour Commission,
P.O. Box 2266,
Thunder Bay, Ontario
P7B 5E8

Mr. Ian Brown,
Port Manager,
Toronto Harbour Commission,
60 Harbour Street,
Toronto, Ontario
M5J 1B7

Mr. E.M. Perkins,
Port Manager,
Hamilton Harbour Commission,
605 James Street North,
Hamilton, Ontario
L8L 1J9

Mr. Charles Gress,
Port Manager,
Windsor Harbour Commission,
500 Riverside Drive West,
Windsor, Ontario
N9A 5K6

Mr. Al Furlong,
Port Manager,
Oshawa Harbour Commission,
1050 Farewell Street,
P.O. Box 492,
Oshawa, Ontario
L1H 6N6

Mr. David Williams,
Senior Research Officer,
CN Marine,
100 Cameron Street,
Moncton, N.B
E1C 5Y6.

Northumberland Ferries Limited,
P.O. Box 634,
54 Queen Street,
Charlottetown, P.E.I.
C1A 7L3

Mr. Kevin Fitzpatrick,
Pelee Island Transportation Services,
Pelee Island, Ontario
N0R 1M0

The Owen Sound Transportation Company Limited,
P.O. Box 336,
1101 First Avenue West,
Owen Sound, Ontario
N4K 5P5

Mr. D. Figurski,
General Manager,
Port of Churchill,
P.O. Box 217,
Churchill, Manitoba
R0B 0E0

Coopérative de Transport Maritime et Aérien (CTMA)
CP 245
Cap-aux-Meules, Québec
G0B 1B0

Société des Traversiers du Québec
Division Bas Saint-Laurent
CP 520
Matane-sur-Mer, Québec
G4W 3P5

La Traverse Riviére-du-Loup/Saint-Siméon Limitée
CP 730, Succursale B
1155 ouest, boulevard Dorchester
Montréal, P.Q.
H3B 3K4

Traverse Trois-Pistoles/Escoumins Limitée
CP 778
195 ouest, rue Notre-Dame
Trois-Pistoles, Quebec
G0L 4K0

M. Dominic Taddeo
General Manager
Port of Montreal
Port of Montreal Building
Cité du Havre
Montreal, Quebec
H3C 3R5

M. Serge Tremblay
General Manager
Port of Sept-Iles
P.O. Box 280
Sept-Iles, Quebec
G4R 4K5

M. Guy Degagné
General Manager
Ports of Chicoutimi and Bai des Ha! Ha!
P.O. Box 760
Chicoutimi, Quebec
G7H 5E1

M. Henri Allard
General Manager
Port of Quebec
P.O. Box 2268
Quebec, Quebec
G1K 7P7

M. Paul Alain
General Manager
Port of Trois-Riviéres
P.O. Box 999
Trois-Riviéres, Quebec
G9A 5K2

Logistec Navigation Inc.
360 ouest, rue Saint-Jacques
Suite 1500
Montreal, Québec
H2Y 1P5

Government of Newfoundland and Labrador
Department of Development

M. W. MULCAHY, P.Eng.
DIRECTOR
SPECIAL PROJECTS

OUNDLAND AND LABRADOR
PMENT

P. O. Box 4750 St. John's
Newfoundland A1C 5T7
Telephone (709) 737-2510
Telex: 016-4949

4th Floor
Atlantic Place

June 7, 1984

German & Milne Inc.
130 Slater St, Suite 630
Ottawa, Ontario
K1P 6E2

Attention: Mr. Bruce Colbourne

Dear Mr. Colbourne:

Further to our meeting of June 5/84 and subsequent review of the ACIB Trials Report for 1982/83 we would like to confirm our interest in the ACIB as a means of extending the winter navigation season to a port in Lake Melville. We see the potential applications of an ACIB to include ice management in the immediate proximity of the dock, breaking of a navigation channel in Lake Melville and extending winter navigation into Goose Bay itself, an area currently believed inaccessable to conventional icebreakers.

While the capabilities of the ACIB for breaking uniform ice up to 1.0 m have been demonstrated, its ability to transit ridges, a common phenomenon in Lake Melville, warrants further study. We would be most interested in any further efforts in this regard particularly if such a program were to include testing of the ACIB in Lake Melville.

We would appreciate being kept informed of any further development work respecting the ACIB. I suggest any correspondence or communication in this regard be directed to Mr. Ivan Ford who you met during your recent visit.

Yours truly,

M.W. MULCAHY, P. Eng.
Director, Special Projects

cc: I. Ford
G. Greenland
C. Granter

MWM/jr

THE TORONTO HARBOUR COMMISSIONERS

Monte Kwinter Chairman
David H Wishart F C A
Tom Clifford
Andrew Pator
Frederick Eisen

I C R Brown General Manager
Gary F Reid, Secretary

848-G-1

April 24, 1984

Mr. Bruce Colbourne
German & Milne Inc.
130 Slater St., Suite 630
Ottawa, Ontario K1P 6E2

Dear Sir:

Thank you for including the Port of Toronto in your study of ice breaking requirements of Canadian users.

I have attached the completed questionnaire and look forward to receiving a summary and specifications of your study results.

Yours truly,

K. J. Gilbert
Director, Projects & Design

LR:cm
attach.

QUESTIONNAIRE - ICEBREAKING REQUIREMENTS

PORT: Toronto RESPONDENT: K. J. Gilbert, P. Eng.

TITLE: Director, Projects & Design

1. In what areas is ice cleared at present?

   ** North Shore - Inner Harbour

2. Who is responsible for ice clearance?

   ** Private Contractor

3. What equipment is used for icebreaking?

   ** Tugs

4. Is present ice management system satisfactory? ** Yes

   If answer is no, what improvement is desirable? Please indicate the part that improved icebreaking capability could play.

5. Can you see any economic benifit from improved icebreaking capability. If answer is yes please give an estimate of dollar value.

   ** No

6. Would Port Authority be interested in the purchase or charter of an ACIB for local ice management?

   ** No

7. What are dimensions of largest ship using the port?

   ** 222.5m x 23.16m

8. Are tugs available locally which could be used to push an ACIB? Please give names of tugs and owners.

   ** G.W. Rogers and Bagotville - Canadian Dredge & Dock Co. Limited

9. Please complete the attached table with average values:

10. Please attach a map of the port showing the limit of ice for each month and the areas in which ridging occurs (indicate average thickness). Use map to indicate any special features or areas which require particular attention, slips and jetties, for example.

QUESTIONNAIRE, Page 2

ENVIRONMENTAL Information

MONTH	Ice Thickness (cm)		Ambient Temp. (°C)		Wind Velocity (m/s)		Snowfall (cm)
	Av.	Max.	Av.	Max.	Av.	Max.	
Dec.	3	20	-1.6°C	-4.6°C	6.2	16	34
Jan.	25	40	-4.6	-7.9	6.7	13	36
Feb.	40	60	-3.9	-7.2	5.7	12	29
Mar.	35	65	0.7	-2.6	5.9	12	25
Apr.	-	10	7.6	3.4	5.4	16	8

PORT OF CHURCHILL
PORT DE CHURCHILL

P.O. Box 217
Churchill, Man.
R0B 0E0

C.P. 217
Churchill (Man.)
R0B 0E0

Tel. (204) 675-8823

Telex 0766-6513

March 20, 1984

German & Milne Inc.
130 Slater Street, Suite 630
Ottawa, Ontario
K1P 6E2

Attention: Bruce Colbourne

Dear Sir:

In reply to your letter of March 9, 1984, enclosed is the completed questionnaire - Icebreaking Requirements.

Yours truly,

T. E. Wokes
Superintendent of Works

/srw

Encl. (3)

to B. Colbourne

QUESTIONNAIRE - ICEBREAKING REQUIREMENTS

PORT: CHURCHILL RESPONDENT: A. E. WOKES

TITLE: SUPERINTENDENT OF WORKS

1. In what areas is ice cleared at present? IF REQUIRED, BERTH APPROACH & BERTHING AREA.

2. Who is responsible for ice clearance? PORT WOULD REQUEST. C.C.G. WOULD PROVIDE SERVICE.

3. What equipment is used for icebreaking? CONVENTIONAL ICE BREAKERS, C.C.G.

4. Is present ice management system satisfactory? ADEQUATE
If answer is no, what improvement is desirable? Please indicate the part that improved icebreaking capability could play.

5. Can you see any economic benifit from improved icebreaking capability. If answer is yes please give an estimate of dollar value. VALUE UNKNOWN

6. Would Port Authority be interested in the purchase or charter of an ACIB for local ice management? Possibly - HISTORICALY NEED HAS NOT EXISTED FOR SUCH A CRAFT

7. What are dimensions of largest ship using the port? 220 M x 32 M

8. Are tugs available locally which could be used to push an ACIB? Please give names of tugs and owners. Yes. Ports Canada owned, M.V. "George Kydd" & M.V. "W.N. Twolan"

9. Please complete the attached table with average values:

10. Please attach a map of the port showing the limit of ice for each month and the areas in which ridging occurs (indicate average thickness). Use map to indicate any special features or areas which require particular attention, slips and jetties, for example.

ENVIRONMENTAL Information

MONTH	Ice Thickness (cm)		Ambient Temp. (°C)		Wind Velocity (m/s)		Snowfall (cm) long term ave.
	Av.	Max.	Av.	Max.	Av.	Max.	
June			6.09	31	5.75	30.27	
July	SEE	BELOW	12.84	33.8	5.36	26.94	
October			-1.4	+10	6.91	35.6	18 - 20 cm
November			-12.6	+5	7.11	35.88	41.6 cm
ANNUAL	MEAN TEMP -7.15 C						

Note: River breakup usually mid June. Ice thickness at time of breakup 1.8 M. Floe ice will drift back and forth with the tide occasionaly till mid July. Floe ice thickness varies 1M to rafted ridge ice 9 - 10M thickness. Concentration varies with local weather, mainly wind and direction of wind.

Fall ice formation commences about mid October. Initial ice is of fresh water, forms on tide flats, flow is from inland to sea, can be greatly augmented by a heavy snow fall in local area and inland. Continues to form land out towards center of River, harbour flow is always from inland to sea.

Harbour entrance, approach & berthing area usually flush out on each ebb tide unless a strong wind holds ice in harbour. This flushing action continues until river mouth is obstructed by sea ice. At that time harbour ice solidifies. Generally mid November to end of November during a period of -30 to -35° weather.

No attempt is made to take ice thickness measurements until ice has ceased to shift on the tide for several days and it is considered safe to send someone out on it, usually early to mid December

March 16, 1984

QUESTIONNAIRE - ICEBREAKING REQUIREMENTS

Windsor Harbour Commission,
500 Riverside Drive West, Windsor, Ontario, N9A 5K6

PORT: WINDSOR RESPONDENT: C. Gress, General Manager

TITLE: General Manager

1. In what areas is ice cleared at present?
2. Who is responsible for ice clearance?
3. What equipment is used for icebreaking?

*We are the Canadian section of the Detroit River between Windsor, Ontario, and Detroit, Michigan, an area of approximately 14 miles. This section of the Seaway is basically ice free throughout the year and ice in our area is not of substantial concern.

4. Is present ice management system satisfactory?
   If answer is no, what improvement is desirable? Please indicate the part that improved icebreaking capability could play.

5. Can you see any economic benifit from improved icebreaking capability. If answer is yes please give an estimate of dollar value.

6. Would Port Authority be interested in the purchase or charter of an ACIB for local ice management?

7. What are dimensions of largest ship using the port?

8. Are tugs available locally which could be used to push an ACIB? Please give names of tugs and owners.

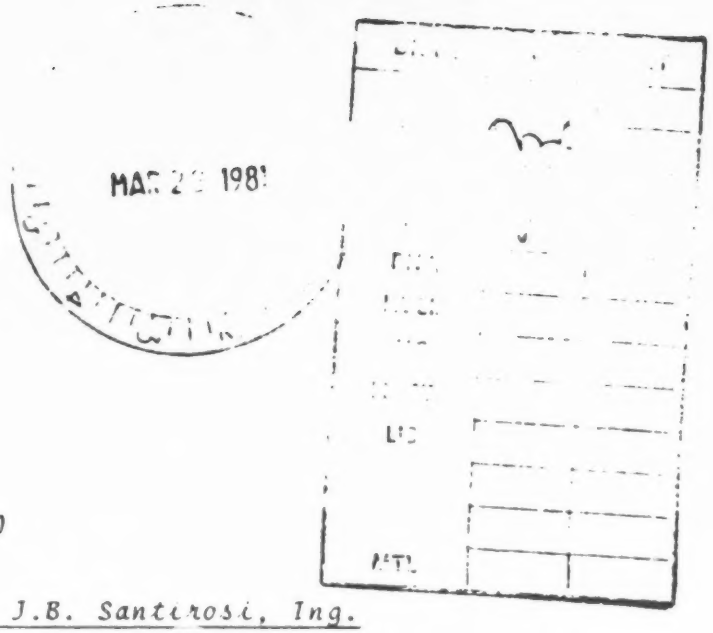
9. Please complete the attached table with average values:

10. Please attach a map of the port showing the limit of ice for each month and the areas in which ridging occurs (indicate average thickness). Use map to indicate any special features or areas which require particular attention, slips and jetties, for example.

Ports Canada

Port de Québec
10, rue de Quercy
Québec (Québec)
G1K 7P7

Port of Quebec
10 de Quercy Street
Quebec Quebec
G1K 7P7



Le 26 mars 1984

German & Milne Inc.
130, rue Slater, suite 630
OTTAWA, Ontario
K1P 6E2
A l'attention de Monsieur J.B. Santirosi, Ing.

Objet: Véhicule à coussin d'air de proue, VCAP "Air Cushion Icebreaking Bow, ACIB"

Monsieur,

La présente fait suite à votre lettre du 13 mars dernier concernant le sujet mentionné en rubrique. Nous désirons vous informer que le Port de Québec ne voit pas l'utilisation d'un tel service.

Veuillez agréer, Monsieur, l'expression de mes sentiments les meilleurs.

Le directeur général,

Paul Henri Allard.

/LG

Canada

PORT OF THUNDER BAY

Lakehead Harbour Commission: P O Box 2266, Thunder Bay, Ontario P7B 5E8 Telephone (807) 344-3594 Telex 073-4347

April 3, 1984.

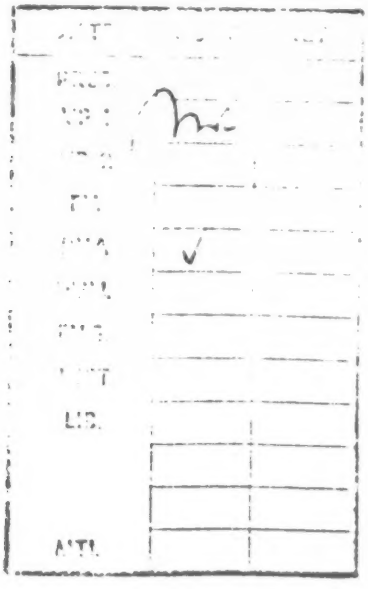
Mr. Bruce Colbourne,
German & Milne Inc.,
130 Slater Street, Ste. 630,
OTTAWA, Ontario.
K1P 6E2

Dear Sir:

RE: Your File No. 7113

In reply to your letter dated March 9, 1984, directed to Mr. P. R. Cook, Port Manager, I have answered most of the questions you requested with the exception of the environmental information. Unfortunately, we do not keep records of this type at our offices.

I hope that we have answered the questions to your satisfaction, and if you require further clarification, please do not hesitate to call.



Yours truly,

LAKEHEAD HARBOUR COMMISSION,

CAPT. R. J. LEGROS,
Harbour Master.

RJL/eb
encl.

Commissioners:
Patrick J. Gilbride, Chairman — Dennis E. Johnson — Walter J. Clemens — Constantine Glymitsas — James H. Simpson — P.R. (Jerry) Cook, Port Manager

QUESTIONNAIRE - ICEBREAKING REQUIREMENTS

PORT: Thunder Bay RESPONDENT: Capt. R. J. Lellis

TITLE: Harbour Master

1. In what areas is ice cleared at present?
   Kam River, Mission River, Main Harbour, North Main Harbour
   C.G.T. Coal Dock, Main Harbour South
2. Who is responsible for ice clearance?
   Coast Guard, Transport Canada
3. What equipment is used for icebreaking?
   Bird Haul Excavator, A.O. Deer Heavy Ice Breaker
4. Is present ice management system satisfactory? yes but can be improved
   If answer is no, what improvement is desirable? Please indicate the part that improved icebreaking capability could play. Harbour, Kaministiquia River could be cleared earlier in many ice seasons. Also, [illegible]
5. Can you see any economic benifit from improved icebreaking capability. If answer is yes please give an estimate of dollar value. No
6. Would Port Authority be interested in the purchase or charter of an ACIB for local ice management? No
7. What are dimensions of largest ship using the port? Length - 730 ft
   [illegible]
8. Are tugs available locally which could be used to push an ACIB? Please give names of tugs and owners. Yes. Tugs - The Great Lakes Towing Co. Ltd. Clearly [illegible]
9. Please complete the attached table with average values: –
10. Please attach a map of the port showing the limit of ice for each month and the areas in which ridging occurs (indicate average thickness). Use map to indicate any special features or areas which require particular attention, slips and jetties, for example. Ridging only seldom occurs in this area because of the protecting breakwall. We usually get North-West and North-East winds.

QUESTIONNAIRE, Page 2

ENVIRONMENTAL Information

MONTH	Ice Thickness (cm.)		Ambient Temp. (°C)		Wind Velocity (m/s)		Snowfall (cm)
	Av.	Max.	Av.	Max.	Av.	Max.	
DEC.	10	15					
JAN.	.	75					
FEB.	.	75					
MARCH	10	10					
APRIL	15	10					

[illegible] the ice thickness the end of the month [illegible] the season

The [illegible] experimental [illegible]. The last [illegible] at the office

K. J. Lyon

APPENDIX 2

HCL REPORT

APPENDIX TO
ADVANCED ACIB CONCEPTS
DESIGN STUDY

J.E. Rapson & M. J. Cox

Hovercraft Consultants Limited

Forest Lodge West, Fawley Road,
Hythe, Southampton,
Hampshire, SO4 6ZZ, UK.

Prepared for:
German & Milne Inc.
Purchase Order No. 02882

July 1984

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1.0 INTRODUCTION

In September 1983 Hovercraft Consultants Limited (HCL) was asked to submit a proposal to provide hovercraft expertise for two designs of air cushion icebreaking bows (ACIBs) for ice 1 m and 2 m thick. On 30th September 1983, HCL submitted a Statement of Work covering its contribution. HCL was advised by telex on 23rd January 1984 that German & Milne Inc. (G&M) had been awarded a contract for an ACIB study. Although HCL worked on the project during March and April 1984, it did not receive a Purchase Order until the beginning of May. This Purchase Order called for work to be carried out in accordance with HCL's telex of 30th September 1983. This is reproduced in the next section. The Statement of Work called for two meetings between HCL and G&M to take place. This resulted in Mr. Rapson visiting Ottawa at the end of April and Mr. Markham visiting HCL in the middle of June 1984.

2.0 SCOPE OF WORK

Extract from HCL telex of 30th September 1984:

"1. Contribute to German & Milne's user requirements and initial performance specifications.

2. Contribute to candidate general arrangements to meet requirements.

3. Review implications of candidate GAs on skirt design, handling and power requirements leading to selection of one design.

4. Provide conceptual skirt design with material recommendations.

5. Design, construct and test a simple skirt model.

6. Recommend lift power requirements and layout.

7. Contribute to general arrangement of selected design and comment on skirt maintenance procedures, spray suppression systems, methods of operation, etc.

It is assumed that Items 2. and 4. would involve a visit by HCL to Ottawa and that Items 6. and 7. will involve a visit by German & Milne to Southampton."

The target date for completion of the work was given as 30th June 1984 but this was amended during Mr. Markham's visit to mid July.

3.0 EVOLUTION OF PRELIMINARY DESIGNS

From the experience gained by G&M in operating the HSL533 ACIB for the Canadian Coast Guard during the winters of 1982/83 and 1983/84, the company was in a good position to suggest the initial design parameters for both platforms. As a result of telephone discussions and correspondence between G&M and HCL, a pair of preliminary general arrangement drawings was produced prior to Mr. Rapson's visit to Ottawa.

3.1 Inland Waters ACIB

The inland waters ACIB was based on a circular platform with no notch. This planform was chosen as being the most appropriate for the method of icebreaking exhibited by the ACT100 and the HSL533. Experience with these platforms confirmed that the theoretical analysis of slow speed icebreaking showed that failure followed the creation of a pattern of radial and circumferential cracks. Since the HSL-533 was based on a square planform with rounded corners, the circular planform was only a minor departure from this shape and hence the practical icebreaking experience gained would still be applicable.

There were several other advantages in adopting the circular platform which would help to reduce first cost, operating costs and general complexity. In the first instance, the lift power requirements for a given lifting area are optimised and, perhaps more significantly, the skirt components could be designed to be identical around the whole of the periphery.

In order to take every advantage of the circular planform, it must be assumed that no notch is incorporated in the platform. Much discussion has taken place on this topic but no evidence has been produced that a notch is necessary or even desirable for the successful operation of an ACIB. If

no notch is incorporated, it is important that the platform is constrained relative to the bow of the pushing vessel so that it cannot yaw away from the centreline. It is clear that an air cushion platform operating over an ice edge merely breaks the ice sheet but does not disperse it and, hence, there can be little difference in the ice flow mechanism from a notch or unnotched platform. In each case, ice lumps emerge from the after edge of the platform periphery with little or no lateral velocity. The bow shape of the pusher vessel provides the means for propelling the ice lumps to the sides of that vessel.

Experience has shown that it is essential to break a path in the ice sheet wider than the width of the pushing vessel in order to minimise the thrust requirements of the vessel resulting from ice contact along its sides. It has been argued that as ice lumps emerge from the cushion, they would be given a velocity at right angles to the local cushion edge. However, an analysis of the energy that can be imparted by the escaping cushion air to the ice lumps that are virtually submerged shows that it is insufficient in the time available to impart any significant velocity to them.

Additionally, it may be argued that a reduction of resistance may be achieved by the use of a notch, for the following reasons.

(1) The inclusion of the ship's bow as part of the cushion seal involves less skirt wetted area.

(2) The depressed water surface (caused by the air cushion) around the bow gives rise to less wetted hull area.

(3) The depressed water surface around the bow gives rise to less ship wavemaking resistance.

Unless the notch is sufficiently deep to incorporate a significant proportion of the ship's beam, these effects are considered to be very small. A deep notch would imply a longer platform to maintain ice failure ahead of the ship's bow and any savings would have to be balanced against the higher power requirement due to longer cushion periphery

3.2 Mid Arctic ACIB

The problems of breaking ice 2 m thick are considerably greater than those likely to be encountered when breaking 1 m ice. The design of a 2 m icebreaking bow cannot be supported by practical experience which, to date, extends to ice thicknesses of only about 0.8 m. The main difference between the two concepts lies in the generation and containment of cushion pressures of the order of 20 kPa compared with half this pressure for the 1 m icebreaking bow. Since the mechanism of slow speed icebreaking depends on creating a cantilevered tongue of ice unsupported by water, breaking under

its own weight, this gives rise to the concept of a critical length of ice (in the direction of approach of the ACIB) which will just fail to support its own weight. The critical length will depend on the ice thickness and on the condition of the ice. The effectiveness of the icebreaking will also vary with the flexibility of the ice. Thus, an ice sheet in the break-up season might be sufficiently flexible to allow an unsupported tongue to droop to the extent that it would be partially supported by the water surface beneath it.

These factors lead to the consideration of a sidewall ACIB concept in which the pressure of the leading edges of the sidewalls on the ice surface would contribute to the icebreaking process. In practical terms, the critical length of 2 m thick ice was about 40% greater than that of 1 m ice. This suggested that, since the path width to be created would continue to be related to the beam of the following ship, the length:beam ratio of the ACIB for 2 m ice would be less than that for 1 m ice. In the initial design, the length was approximately 27 m and the beam 32 m. In spite of this length:beam ratio, there is a significant saving in installed power due to there being very little air leakage under the sidewalls.

The width chosen for the lower edges of the sidewalls will depend on the preferred method of icebreaking. If it

were considered that very high local pressures on the ice were desirable, a narrow sidewall would be appropriate. More robust, wider sidewalls could be used if high bending moments, due to weight being applied at the end of the ice tongue, were significant.

The possible mechanisms of icebreaking using a sidewall ACIB are discussed later in the report. It seems likely that the testing of a hovering model in an ice tank will be required in order to establish the most effective mechanism.

If more detailed investigations suggest that the sidewall ACIB concept is not practicable, the logical alternative is to scale-up the circular ACIB design. Although the requirement is to break ice twice as thick as that designated for the small circular ACIB, the critical ice length is not twice as great. Hence it will be necessary to establish the cushion diameter on the basis of the required width of the broken ice channel and the need to exceed the critical length of 2 m thick ice. This could lead to an oval or elliptical planform, having a beam greater than its length. By careful design, it might be possible to retain the concept of identical segments around the whole of the periphery. It would be advisable to carry out some simple model tests to assess the practicability of this alternative concept for an ACIB for 2 m ice.

4.0 ESTABLISHMENT OF DESIGN PARAMETERS FOR CIRCULAR ACIB

4.1 General

From an early stage it was felt that the favoured circular planform would enable very simple skirt segments to be designed to contain the cushion. In order to support this belief, HCL designed and built a 1/16th scale model (Figure 1). This was used primarily to test the simple segmented skirt selected for the full scale design. It was also used to establish the stiffness of the basic platform in pitch and roll, and later to evaluate optimum operating techniques.

4.2 Installed Power

From theoretical considerations and experience of the ACT100, the HSL533 and other hoverplatforms, an appropriate airflow was established for the platform when operating at its maximum all up weight (AUW). The cushion pressure had been determined allowing a small margin over the pressure required to create a water pressure to the depth of the bottom of the ice sheet. The diameter had been established by G&M on the basis of:

(i) creating a broken ice path wider than the pushing vessel;

(ii) creating an adequate width of path through ice flows after two passes of the pusher/ACIB combination; and

(iii) ensuring that the resulting platform would pass through certain strategic canals.

The conceptual layout of the platform allowed for an air distribution duct around the periphery of the platform. This reduced duct losses to a minimum. Since the cushion was to be uncompartmented, the losses between the duct and the cushion were negligible and the overall efficiency of air generation was relatively high.

Once the power requirements had been established, an allowance was made for auxiliary power for the driving of winches and the provision of electrical power, including power for heating. Power plants were then chosen which would provide this power level under all conditions.

4.3 Model Details

The model construction was based on, and built around, two flat plywood discs. The accuracy of the model relied on its initial structure being flat, so a good quality ply 6 mm was used to form these two discs. The two discs were separated by a box-like structure in the centre of the model and by a series of thirty radial ribs equispaced around its circumference. These ribs also formed the internal structure of the plenum chamber. Again accuracy was important and the trueness of the model depended upon a constant height of rig

and, for this reason, they were cut from good quality 3 mm ply with the aid of a metal template.

The initial structure, consisting the discs, ribs and box spacer, was glued over a good, flat and plane surface using a slow setting glue and weights to hold the structure true and square while the glue set. A ply ring was added to the outer ends of the ribs to form a guide for the outer wall of the plenum chamber and to provide the outer-upper attachment point for the skirt. The plenum chamber was completed by adding two 1.5 mm ply collars to form the inner and outer walls of the chamber. A 6 mm ply annular roof was added to complete the air seal. Half ribs were added between every structural rib in order to provide the necessary sixty attachment lines for the skirt. This completed the main wooden structure of the model which was then ready to receive the skirt (Figure 2).

The skirt was built from special lightweight and flexible red sailcloth and, again, accuracy dictated that a template was employed to cut the sixty segment blanks required for this skirt. Stiff stainless steel wire was used to form part of the attachment of the segments to the hull and special plastic clips were made to clip each separate segment to its mounting rib on the underside of the model. This made each individual segment removable. The

upper-outer attachment was provided by a foldover tab on the segment which was fixed to the model by means of a thin ply band and staples (Figure 3).

Spray skirts and drag sheets were also added to the model at a later date. These too were made from lightweight blue flexible cloth. These were attached by means of thumbtacks and "Velcro", in order that they could easily be removed to be altered or changed for a different system.

After the model testing had been completed, deck and deckhouses were built from expanded polystyrene foam. They were simply placed on top of the test model structure and used to provide a photographic representation of the full size craft (Figure 4).

The model had been designed to be operated over a pair of transparent topped tables (each 4 ft. by 6 ft.). A wooden section (2 ft. by 6 ft.) was fitted between the tables to provide a level hovering surface of 10 ft. by 6 ft. An air supply pipe of 6 in. diameter, fed from an electrically powered centrifugal fan, was attached to a central port in the wooden section. This unit could be throttled so that the volume flow for lifting the model could be varied. The fan intake tapping was calibrated using a long settling tube to measure the velocity profiles at various intake depressions. Thereafter, volume flows through the model were calculated

from electronic manometer readings of the fan intake depression.

4.4 Skirt Design

One of the difficulties experienced during the operation of the HSL533 was the deterioration of skirt segments. Due to their design, they could not be stored flat and it was found that prolonged storage of the creased or folded material caused lines of weakness leading eventually to skirt failure. There was, thus, a strong incentive to design the skirt segments without knuckles so that they could be stored in a flat condition. This, in turn, implied a loss of potential cushion area for a given structural diameter. However, since a high cushion pressure was desirable, the only anxiety lay in the possible loss of pitch and roll stability that this skirt design dictated. Tests on an earlier HCL model, built for a different purpose, had shown that a segment face angle of 45° would give an acceptable pitch and roll stiffness. The skirt was, therefore, designed to achieve this face angle when inflated.

To minimise the effect of possible damage to the bottom of the platform from ice lumps, the cushion depth was set to 2 m. This helped to establish the pitch of the segment on the basis of previous designs using this type of skirt. It was decided to fit sixty identical segments around the

periphery, giving a segment pitch at the junction with the structure of 1.24 m. A planing surface above the segment was specified to give a rise of 1 m from the central part of the bottom to the outer edge. The developed shape of each segment is shown in Figure 5.

The choice of a circular planform simplified the problem of changing segments after they had become worn or damaged. Each segment was to be hung from two beams which would be attached radially on the planing part of the bottom of the structure. A possible attachment system is shown in Figure 6. A flap on the segment would then be attached to a portion of the side of the structure, each by means of a separate plate. It was visualised that by building a gantry or small crane which could be run on rails around the outside edge of the platform, segments could be withdrawn for replacement. A damaged segment would be freed by removing a plate on its top outer edge and the gantry lined up with the two separate beams. These would be drawn out radially until the segment was clear of the craft. The replacement segment which would be stored in the enclosure on the deck (probably with its beams attached), would be fitted by reversing the process. It was realised that changing the segment when the

craft was over water would be extremely difficult and it was recommended that such changes should only be carried out at the maintenance base.

4.5 Anti-Scooping Measures

Since an ACIB would normally be propelled in one direction only, it was necessary to prevent the segments at the rear of the platform from scooping ice lumps. Inevitably any closing face on a skirt segment increases the stiffness of the pneumatic structure created and can increase the drag of the platform and the wear of the rear skirts. To minimise these problems, HCL postulated the use of "drag sheets". By arranging for a sheet of material to cover the lower part of three adjacent segments, it was possible to provide a surface which would prevent these segments from scooping with a minimal increase in stiffness. The ends of each drag sheet would then be attached back to the structure of the platform (Figures 7 to 11). This solution, which had been incorporated on other HCL designs, presented, in this instance, the advantage of not having to modify any of the main skirt segments. HCL specified eight such drag sheets around the rear of the craft, covering between the twenty four segments or 144° (72° each side of the centreline). This drag sheet configuration was fitted to the hovering model and evaluated by pulling solid obstacles, similar to the type of ice blocks

which could cause scooping, through the rear skirt (Figure 12). The results, although qualitative, suggested that the design would be satisfactory.

4.6 Spray Suppression

Any hoverplatform operating over a free water surface creates spray. The extent of this spray depends primarily on the cushion pressure of the platform. Although the circular ACIB has only a slightly higher cushion pressure than that of the HSL533, a spray skirt was clearly necessary. Several hovercraft and hoverplatforms have been fitted with spray skirts of different designs. Since the ACIB is limited to low forward speeds, a simple spray skirt arrangement is appropriate. Two potential designs were fitted to the model.

The first consisted of two hanging curtains, each attached to the outer edge of the structure around the periphery. The outer, shorter skirt hung vertically downwards, while the longer, inner skirt (having a small diameter in planform) hung about 0.3 m inboard. The inner curtain was perforated on its upper edge to prevent any build up of pressure inside it (Figures 13 and 14). In operation, spray which was deflected onto the inside of the inner curtain was forced through the perforations onto the inside of the outer

curtain, thereby losing momentum. This configuration allowed the water droplets to fall down between the two curtains with little outward velocity.

The second spray skirt fitted to the model was based on that designed for the HSL533, suitably modified for the changed skirt configuration. This simpler spray skirt consisted of a main circular curtain attached to the outer edge of the structure around the periphery and weighted close to its lower edge. This had perforations near its upper edge which, in turn, were covered by a short, heavy curtain attached from the same position (Figures 4 and 15).

Both of these spray skirts appeared to show promise on the model, although no overwater tests were practicable. It has long been recognised that spray simulation at cushion pressures appropriate to a model is impracticable.

4.7 Pitch and Roll Stiffness

Single cell hovercraft platforms depend on the geometry of their peripheral skirts for their stability in pitch and roll. This is normally defined as the movement of the centre of gravity (CG), as a proportion of the cushion length or beam, required to tilt the platform through one degree of pitch or roll. The model of the circular ACIB was used to carry out a series of tests so that the pitch and roll stiffness could be estimated for a range of AUWs, CG heights

and cushion air flows. Figure 17 shows the model pitched bow-up to an extreme angle of about 18°. Weights and CG heights were provided by G&M while typical values for the air flow requirements were suggested by HCL.

These stiffness tests allowed several curves of the type shown in Figure 16 to be produced. These were all of the same basic shape showing an increase in resistance to tilting as the load was moved further outboard. For the purposes of comparing stiffness under a variety of conditions the average slope of the curves between plus and minus 4° was converted into a value of "CP shift per degree". Neither AUW (or cushion pressure) nor the air flow greatly affected the resulting stiffness but the height of the centre of gravity of the loaded platform produced a significant change. The results can be summarised as follows: stiffness in pitch or roll is 0.75% per degree when the full scale CG is 1.6 m above the bottom of the structure and 0.65% per degree at a CG height of 2.0 m. Stiffness values for the HSL533, calculated from G&M trials, gave values of between 0.5% and 0.6% per degree. When operating the circular ACIB of the current conceptual design, the natural cushion stiffness should be adequate and virtually any desirable trim angle in pitch or roll will be achievable by suitably arranging the disposition of the liquid ballast.

4.8 Operating Techniques

It has been suggested that there might be a reduction in skirt contact (and hence skirt wear) of the ACIB when breaking ice if the platform were kept in a "bow-up" trim condition. Some model tests were, therefore, carried out in which an ice step 1 m thick was simulated and the model pushed slowly over it while resistance was measured. The surface at the lower level was covered with a film of low friction material while the naturally higher friction of the upper level was retained. This provided a rough simulation of the full scale changes in friction between skirt material and water and between skirt material and snow covered ice. An electronic force measuring meter was used to provide the pushing load while the position of the model relative to the ice step was recorded from a marked line passing from the bow over a pulley. The test arrangements are shown in Figure 18.

The results from the tests showed that there was no detectable difference in resistance between step climbing from bow-up static trim angle of 0°, 1° and 2°. By relating the resistance readings to the position of the model relative to the step, it was possible to identify the element of resistance due to the cushion pressure acting against the ice face. The remaining drag could then be attributable to the skirt but, since this was only a small proportion of the

total, no reliable conclusion could be drawn. However, it is clear from Figure 18 that the model which was initially trimmed level, took up an appreciable bow-up attitude when being pushed over the ice step. It should be noted that in full scale icebreaking operations, the "ice step" would rarely be one metre deep and the induced bow-up trim would be relatively small.

5.0 ESTABLISHMENT OF DESIGN PARAMETERS FOR SIDEWALL ACIB

5.1 General

The reasons for suggesting a sidewall hoverplatform for breaking ice up to 2 m thick have already been given in Section 3.2. The method of slow speed icebreaking using this configuration merits further discussion. There are three possible ways in which sidewall ACIBs can break ice, depending to some extent on the geometry of the sidewalls and the cushion pressures employed.

5.1.1. If the bottoms of the sidewalls are constructed so that each has a narrow, strengthened edge, there will be a tendency for these sidewalls to shear their way through an ice sheet if sufficient weight is applied. This action would be similar to that employed by the Wass bow used as an attachment to a standard icebreaker. If the advancing sidewalls shear continuously through the ice sheet a tongue of ice will extend into the cushion. Since this tongue will

gain no support from the icefield outboard of it, it is liable to break off under its weight in the cushion at a shorter critical length than would be the case with the simple ACIB action. It is still necessary, however, to ensure that the depression created by the air cushion is sufficiently deep to ensure that the bubble remains under the tongue of the protruding ice. In order that the weight causing this shearing action is adequate, the cushion must be off-loaded to some extent. For example, it has been calculated that for a sidewall ACIB, having the structural dimensions already selected, the cushion would have to be off-loaded to the extent of 6 kPa in order to ensure that fresh hard ice was sheared. This implies that the normal AUW would have to be increased by 30% in order to provide the extra weight on the sidewalls without reducing the cushion pressure. The additional power required to increase the cushion pressure from 20 kPa to 26 kPa would have to be taken into account when estimating the installed lift power requirement if this icebreaking method is found to be relevant. In practice, this additional power will be used only when the sidewalls are taking no weight.

5.1.2. If the lower edges of the sidewalls were relatively broad and had rounded corners, the shearing action would be minimised. Any weight transferred from the cushion to the sidewalls would produce two discreet loads which would increase the bending moment on any protruding tongue of ice. However, the influence of the air cushion acting on both the upper and lower surfaces of the ice only begins to take effect when the ice sheet has encroached significantly into the cushion space. This action is assisted if the bubble is able to penetrate ahead of the ACIB. Again, it is important that the cushion pressure acting when part of the load is supported on the sidewalls is sufficiently high for the bottom of the depression to reach the under surface of the ice.

5.1.3. If the geometry of the platform were arranged so that the cushion extended well forward of the sidewall leading edges, icebreaking would eventually take place in the conventional ACIB manner. In this case, there would be no offloading of the cushion and the maximum cushion pressure that must be developed would be only about 10% above that corresponding to the ice thickness. The most likely advantage of this configuration would be the saving in lift power compared with a circular platform or the other sidewall variants.

5.2 Installed Power

The power required to generate the air flow needed by the selected sidewall hovercraft design, has been calculated from a knowledge of the air leakage rates of other sidewall hovercraft designs. Power units have been selected to provide this basic power requirement and an allowance for the auxiliary system. It should be noted that if it is found that the icebreaking mechanism dictated that the cushion pressure should be increased from 20 kPa to 26 kPa, this basic power requirement will be increased by about 50%. In this situation, there may be little installed power reduction compared with a larger circular ACIB. The preferred machinery system consists of four prime movers driving four separate fans to an air feed that enters a transverse duct or plenum chamber at the forward end of the platform and to a similar duct at the after end. Such a system reduces losses to a minimum and allows a high overall efficiency to be achieved.

5.3 Cushion Containing Skirts

It is proposed that simple segments without knuckles should be used for both the forward and aft cushion seals.

Although these have been shown on the general arrangement drawing as spanning the forward and aft ends in a straight array, there might be some advantage in forming a curved boundary in planform to the cushion at the forward end. The cushion has been designed to give a hull clearance of about 2.5 m to minimise the risk of large broken lumps of 2 m thick ice from damaging the main hull. It is visualised that the lower edges of the sidewalls would be immersed in the free water surface to reduce the risk of cushion air leakage under the sidewalls. Although skirt segments of this form could be stored flat, they would be larger than those of the circular ACIB and a larger storage area would have to be allowed. The stresses on skirt material would be slightly greater than those of the circular platform but, due to the mounting system proposed, little distortion would be expected.

Due to the greater density of the sidewall platform, the skirt segments will probably be completely immersed in water when off-cushion. It seems, therefore, unlikely that skirt changes could be contemplated without "beaching" the platform. However, in order to minimise the effects of material distortion under pressure, the upper edges of the segments must be attached to the underside of the hull in such a way that no movement at this level could take place. As with the circular platform, it will be necessary to provide a gantry

or crane to draw out the damaged segment in order that it could be replaced. At the risk of some complication, it might be possible to provide a remotely controlled mechanism for this process. This would then enable an attempt to be made to change segments when the platform is off-cushion. Alternatively, it might be possible to change segments while on-cushion. The damaged segment would be ejected by cushion pressure once the outside restraining plate had been removed. The replacement segment, if suitably furled, might then be inserted without having to position it against the full influence of the cushion pressure.

5.4 Anti-Scooping Measures

Since all of the segments along the after edge of the platform would tend to catch on the ice lumps, all of the segments in this area must be provided with closed faces on their cushion side. It is again proposed to employ drag sheets, each covering three or more segments. Drag sheets of this form can be stored flat if sufficient space is available.

5.5 Spray Suppression

Spray skirts fitted outside the segments at the forward and aft ends would be somewhat different from those proposed for the circular platform. It might not be practicable to

introduce any transverse tension and the suitability of the spray skirt system would depend on the detailed geometry and on additional weighting. Since the forward and aft seals operate under different conditions, the opportunity can be taken to optimise the design of the spray skirts for each region.

6.0 IMPLICATION OF ACIB DESIGN REQUIREMENTS ON SKIRT CONSTRUCTION METHODS

6.1 Skirt Material Requirements for Circular ACIB

The platform has been designed with sixty identical segments, each having a nominal face angle of 45°. The pitch of the segments at the upper edge is 1.24 m and at the lower edge is 0.92 m. The selection of sixty segments was made on the basis of keeping the number of skirt components to a minimum while achieving an acceptable tension in the material.

The loads on the pressure faces of the segments can be arranged to be in line with the warp threads of the material and, provided that the upper attachments of the segments are made to prevent any longitudinal (radial) movement, these loads can be transmitted directly back into the structure. Thus, there will be virtually no shear loads in the segment material and the overall distortion will be minimal. Nevertheless, at the design cushion pressure of 11.22 kPa

(234 p.s.f.) the warp tension at the top of the segments is approximately 6.93 kN/m (39.6 lb./in.). The corresponding figure near the tip is 5.14 kN/m (29.3 lb./in.).

The effect of material stretch is to increase the angle of the segment pressure face to the horizontal. Once the segment material is selected and its elongation characteristics known, appropriate measures can be taken in designing the final segment geometry to produce the selected face angle when the platform is operated at its design all up weight. Due allowance must be made for the effects of material stretch characteristics of ageing and of operating in a wet environment.

6.2 Skirt Material Requirements for Sidewall ACIB

On the basis of the skirt components indicated in the GA drawing dated 25th April 1984, the tension in the material due to the cushion pressure of 26 kPa (544 p.s.f.) is approximately 12.96 kN/m (74.0 lb./in.). The normal tensions in the material for this platform are, thus, about 90% greater than in the circular platform. In this case it is, therefore, also very important that the material stretch characteristics are known so that the design segment face angle can be achieved at the design cushion pressure. The requirements for mounting the segments mentioned above are even more significant for this platform.

6.3 Skirt Construction

HCL has, to some extent, avoided the effects of distortion of inflated skirt components by designing to allow the warp threads of the base material to take the largest of the inflation loads. This is possible where the attachments to the hull are continuous and do not allow any movement of the material under load. If it is important to design for the maximum cushion area for a given structural area, as might be the requirement to reduce structural costs, this procedure may not be possible. Such a skirt is likely to consist of a series of segments mounted under a loop or bag. Such a configuration normally requires that the segment loads are transmitted to the hull through the segment tail in a similar manner to the tack of a jib sail on a yacht. With such an arrangement, the stress lines cross both the warp and the weft threads at an acute angle and cause large elongations along the "bias" of the material. This, in turn, distorts the geometry of the inflated segments. Although it may be possible to reduce such distortions by adjusting the developed shape of the segments, changes in cushion pressure will exaggerate the differences from the design shape. An alternative approach is to bond additional material, cut parallel to the warp threads, on to the areas where bias orientated loads predominate. However, this system suffers

from discontinuities at the edges of the applied material. Local stretching and creasing at these edges will result.

Although serious distortions are likely to be avoided in the segments for both the circular and sidewall icebreaking platforms by designing continuously attached segments, such an approach may not always be possible. A promising solution would then be in the use of specially moulded segments. To date, almost all hovercraft skirt components have been fabricated from strips of orthogonally woven material proofed with polymer membranes. Since the stresses in the skirt component of a given geometry can be calculated with reasonable accuracy, it is possible to specify an array of threads or filaments that will be sufficient to sustain the loads in the component with an acceptable degree of stretch. The reinforcing threads must be held in place and this is conveniently achieved by moulding a suitable polymer around them to form a substantially flat sheet. At the expense of a more costly mould, three dimensional shapes can be produced. The load carrying elements of a moulded segment can be visualised as being formed from a laid or plaited synthetic rope loop at the segment tail. The fibres of the rope are progressively separated and spread in a radial formation to terminate at the lightly loaded segment edges. Variations

can be incorporated to match the stresses in the segment and the type of hull attachment selected.

Since the polymer also acts as a means for retaining the air and for protecting the segment from undue wear, the choice of its composition may be made on the basis of these criteria. It is often an advantage to produce proofing with a low coefficient of friction when rubbing over the hovercraft's operating surface. It may be possible to incorporate such a surface material, at least on parts of the outside of the component, during the moulding process.

By using appropriate moulding techniques, the edges of the skirt components can be sealed to protect the structural threads. Sealing the edges will also reduce the ingress of water and the subsequent "wicking" within the fabrication. This advantage can be particularly beneficial for icebreaking platforms where the skirts may be operated in alternate freezing and thawing conditions.

The moulding of hovercraft skirts has long been recognised as offering the opportunity for improving their characteristics. The high setting-up costs are only likely to be justified if large numbers of identical segments are required or if the loads due to cushion pressure indicate that severe distortions will otherwise occur. In either event, the first company to mould hovercraft skirt components

successfully will attract interest from hovercraft manufacturers throughout the world.

7.0 GENERAL DESIGN FEATURES

7.1 Pushing Arrangements

The arrangements for transmitting the pushing force to the ACIB have not been considered in detail but, in the absence of a notch, it would be necessary to fit some external structure to the platform. The pushing force would have to be located within close limits laterally but some attention might be given to the effect of the height of the applied force on the pitch attitude of the platform. The model tests on the circular ACIB gave an indication of the stiffness in pitch of the platform over a range of CG heights and of the increase in bow-up attitude when being pushed up a step. This information would enable an estimate to be made of the effect of applying the propelling force at a number of different vertical positions. Changing these positions might provide a powerful control force which would allow a desired platform pitch attitude to be selected. It might prove desirable to extend the point of application of the force to a position near the centre of the platform. The effective cushion pressure might then be varied by transferring a small proportion of the weight of the ship on to the platform. This could be particularly beneficial in the operation of the

sidewall ACIB, although the engines and fans would have to be selected so that the higher cushion pressure air could be generated. The directional control of the pusher tug/ACIB combination might be increased by offsetting the ACIB from the centreline of the ship by adjusting the winch lines connecting the two elements. The resistance of the ACIB would then tend to act to port or starboard of the ship centreline and induce an appropriate turning moment. Further model testing could be used to assess these aspects prior to the completion of the design of a full scale ACIB.

7.2 Platform Weather Protection

Experience with the operation of the HSL533 has pointed to the importance of provided covered space for the machinery, for the protection of the operating crew and to reduce the level of icing on the structure. It is suggested, therefore, that consideration should be given to the covering of the whole of the deck area with an inflated membrane or "air house". This concept would be particularly appropriate since the ACIB would already have a substantial air supply. Low leakage openings would have to be provided for winch cables, exhausts, cushion and engine air intakes and control runs. The control cabin could protrude through the membrane or window panels could be fitted in appropriate positions. If such an idea were to be seriously considered, the layout

of each of the ACIB designs might require some modifications to take the greatest advantage from the large enclosed and protected volume provided. It is considered that the additional power required for inflating the air house would be negligible and space heating could be achieved by heat transfer from the lift engines. A brief design study of this concept would be beneficial and the retrospective fitting of an air house to the HSL533 might be considered.

8.0 CONCLUSIONS AND RECOMMENDATIONS

The use of an ACIB has been shown to be practicable from the trials with the ACT100 and the HSL533 for ice thicknesses up to about three quarters of a metre. The inland water ACIB concept has extended the technology marginally to the breaking of ice 1 m thick. The risks in designing a 1 m ACIB are, therefore, minimal. There is, however, a considerable incentive to improve the HSL533 design. In particular, by chosing a circular planform without a notch, the skirt elements have been made simpler and all are identical. The use of water ballast will speed up and simplify the achievement of desired platform pitch and roll angles. Model tests have shown that the pitch and roll stiffness of the circular platform is slightly greater than that of the HSL533. The circular platform should have a lower first cost and lower

maintenance costs than its predecessor and since the skirt elements can be stored flat, they will not deteriorate when not in use.

The mid Arctic ACIB is more speculative since it increases the depth of ice to be broken by a factor of about three. A sidewall design has been proposed in the expectation that more efficient icebreaking could be achieved together with a saving of lift power. However, the mechanism of icebreaking has not been established and some model testing in an ice tank will be needed before detailed design work is undertaken. This design also specifies simple skirt segments that can be stored flat. The low length to beam ratio of a rectangular platform will be structurally efficient and the layout offers the opportunity of providing a "low loss" air distribution system. If, after further investigation, the sidewall concept appears to be impracticable, an alternative circular or oval platform based on the inland water design should be studied.

Neither of the designs is fitted with a notch. Although there are no indications that a notched ACIB is likely to provide advantages which outweigh those of a simple unnotched system, further evidence is desirable before a final decision is made.

As cushion pressures increase and the skirt elements increase in size, the loads on the skirt material also increase. Existing materials are probably adequate for the proposed designs although great care will have to be taken to minimise the effects of material stretch, particularly in the bias direction.

Little is yet known about the effects of varying the propelling arrangements for ACIBs. Advantage might be taken of transferring part of the ship's weight on to the platform and the possibility of enhancing the steering ability of the pusher/ACIB are worthy of investigation.

Although most of the controlling of the ACIB is carried out from the parent ship, there would be considerable advantage in being able to protect the crew working on the ACIB. The possibility of designing a special inflated air house has been considered and appears to show considerable promise. It would provide relatively cheap and simple protection for the machinery items on the deck, although special arrangements would have to be made for various items to protrude through the membrane.

The investigation carried out suggests there are no fundamental problems involved in the design of icebreaking bows for 1 m and 2 m ice. However, at various stages of the design process, further work should be carried out on the following subjects.

(1) Further tests on the circular HCL model to assess the effects on skirt drag and skirt wear of operating over a range of trim angles.

(2) The use of the HCL model to evaluate the effect of trim angle and drag when pushing the platform from a range of vertical positions.

(3) The building and testing of a model of the sidewall concept for use in an ice tank. This would enable the mechanism of icebreaking using a sidewall platform to be established and would allow the design to be optimised accordingly.

(4) Tests on the HSL533 to similate operating with and without a notch. These tests would give qualitative results only since, if the notch were to be filled, in the resultant platform would be longer than the minimum length required to break a given thickness of ice.

(5) Use of the HSL533 with the notch filled in, to evaluate, at various pushing heights, the effect on the efficiency of icebreaking and on the for and aft trim of the platform.

(6) Similar tests to ascertain whether the degree of directional control can be increased by using the winch lines as reins.

(7) The fitting of a trial air house to the HSL533 to evaluate its practicability.

(8) In the longer term, the commissioning of a design study in co-operation with a Canadian rubber manufacturer to investigate skirt material and fabrication systems suitable for large icebreaking bows and large hovercraft generally.

(9) The investigation of possible segment moulding techniques with a Canadian rubber manufacturer.

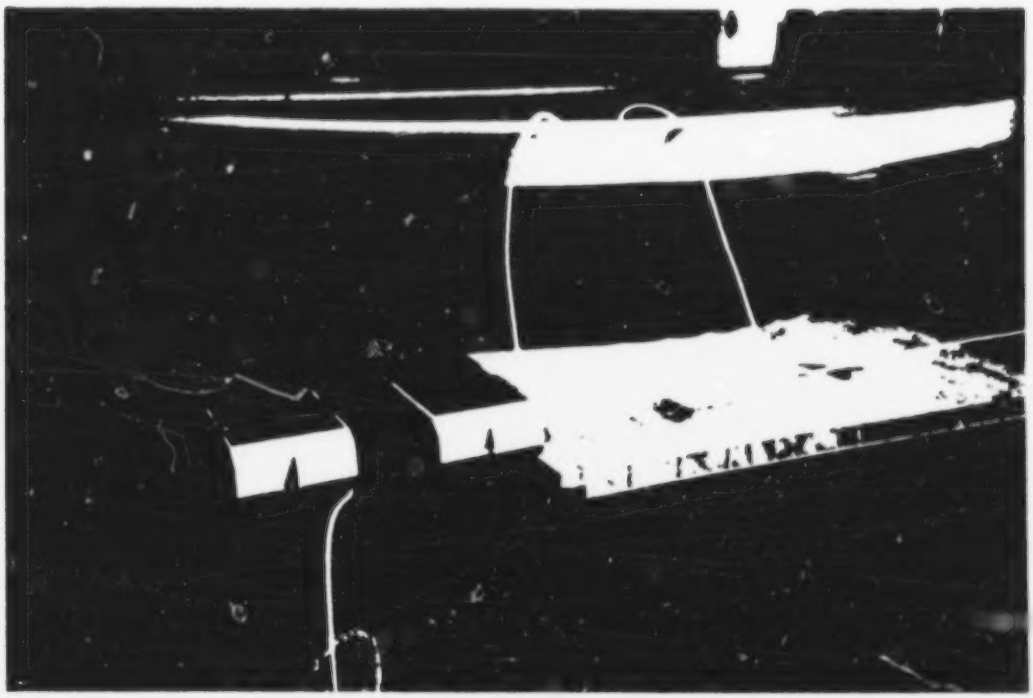


Figure 1 1/16th Scale Model of Circular ACIB

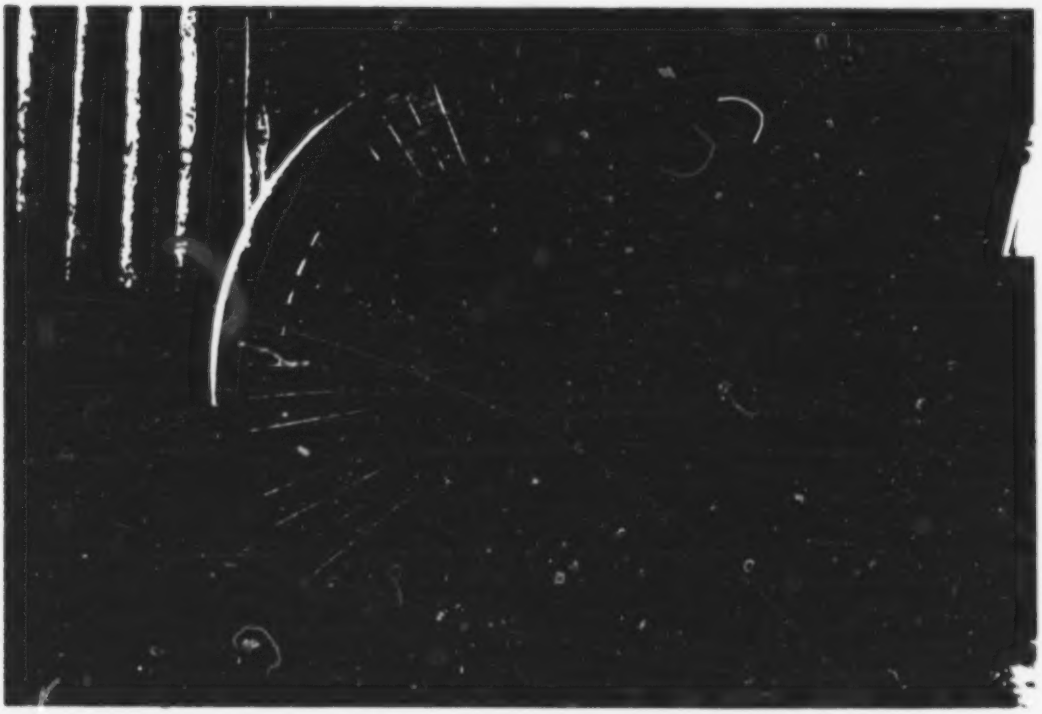


Figure 2 Wooden Structure of Model

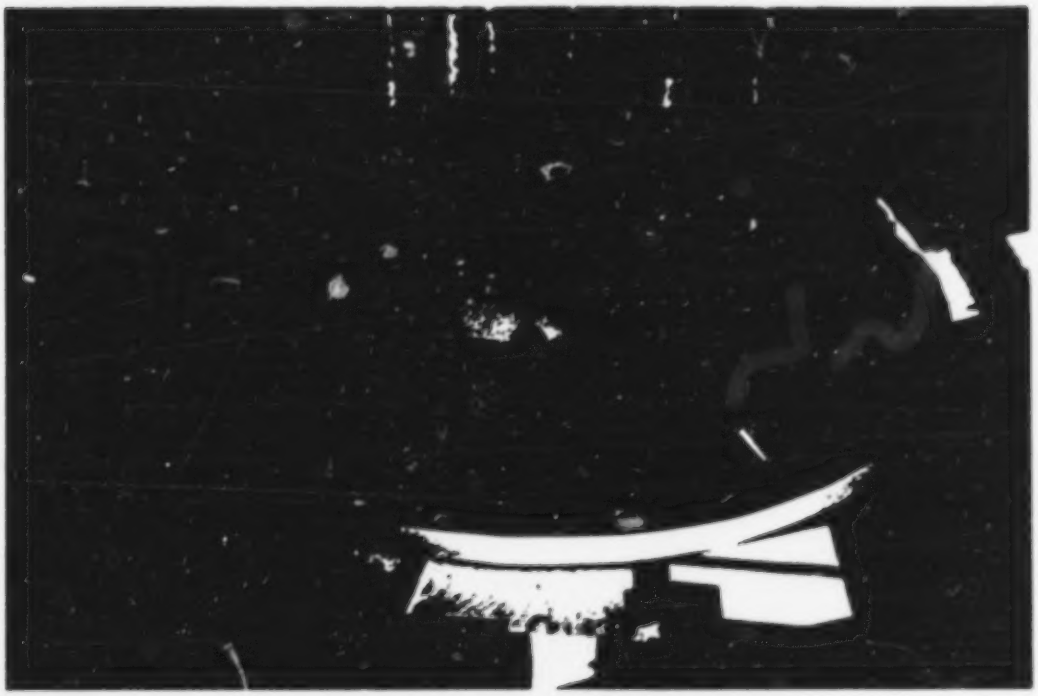


Figure 3 Segments Fitted to Underside of Model

Figure 4 Hovering Model with Superstructure Fitted

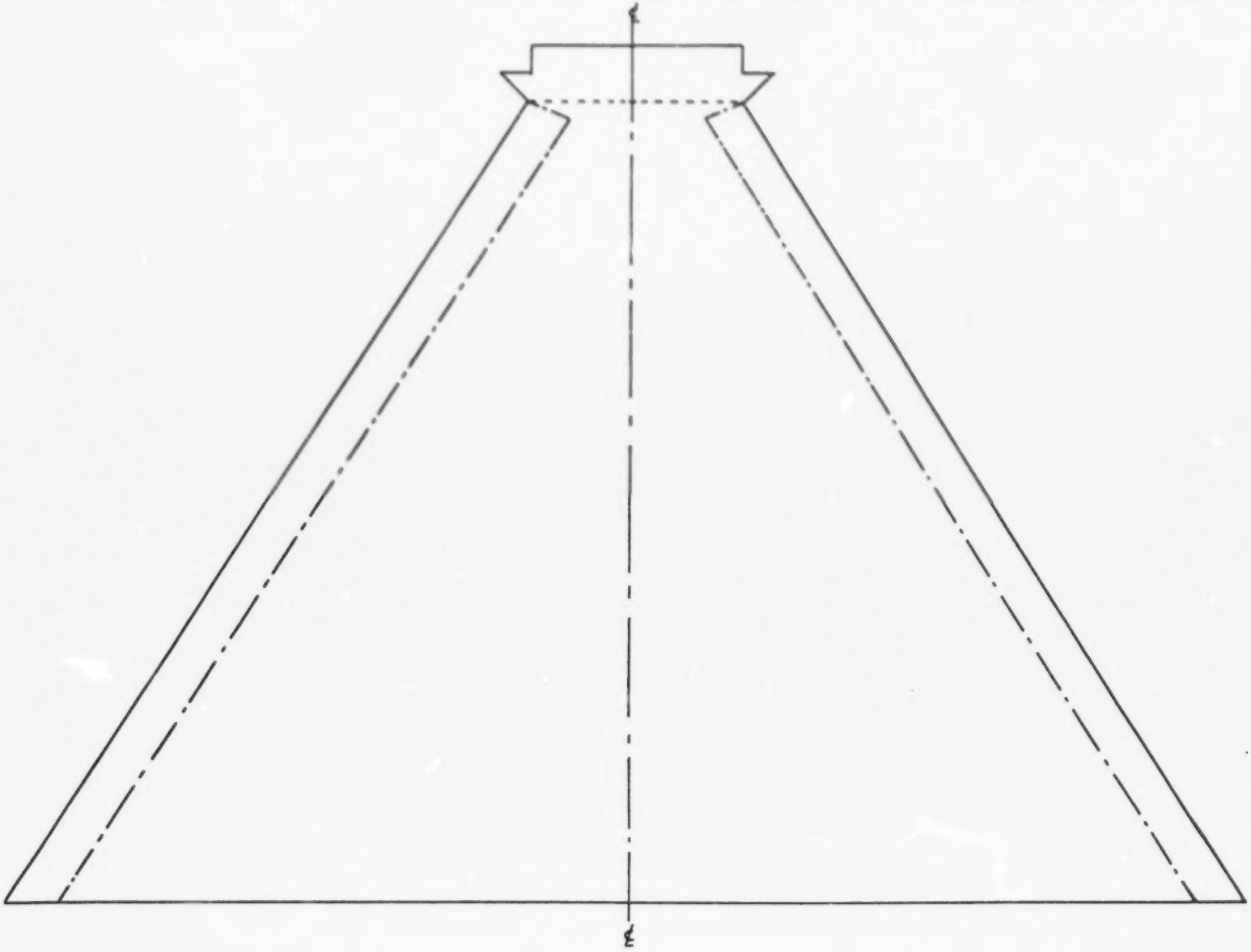


Figure 5 Segment Construction

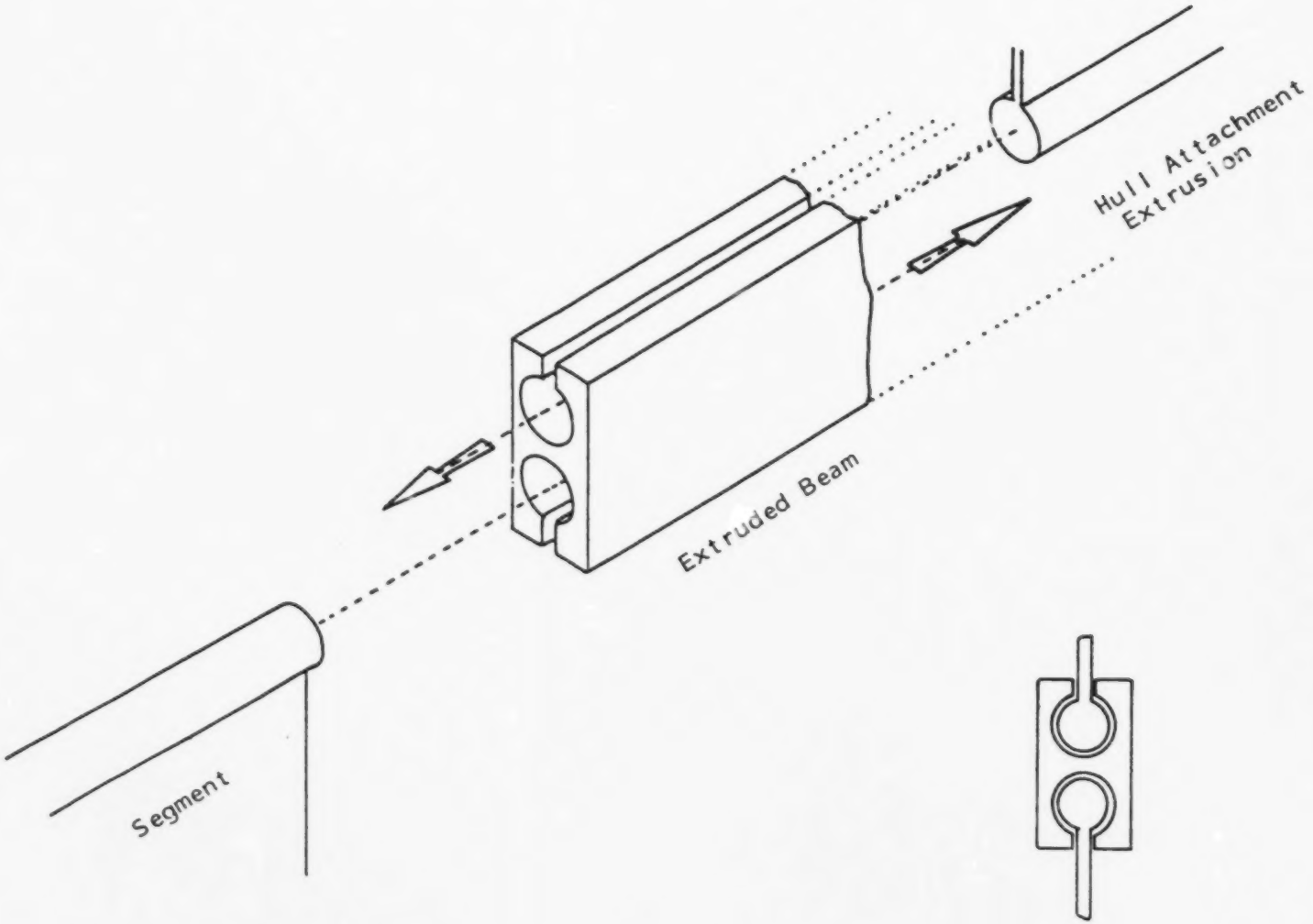


Figure 6 Possible Segment Attachment System

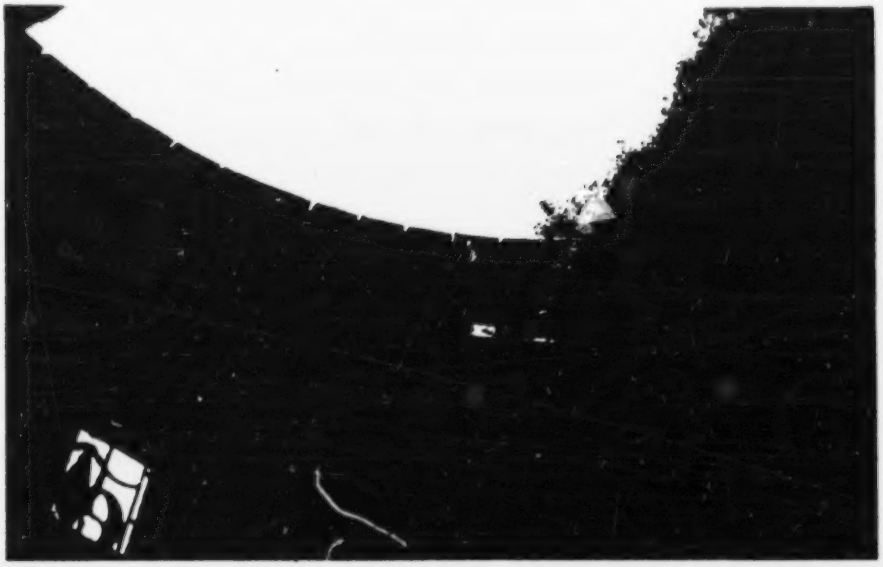


Figure 7 Inflated Segments and Drag Sheets from Underside

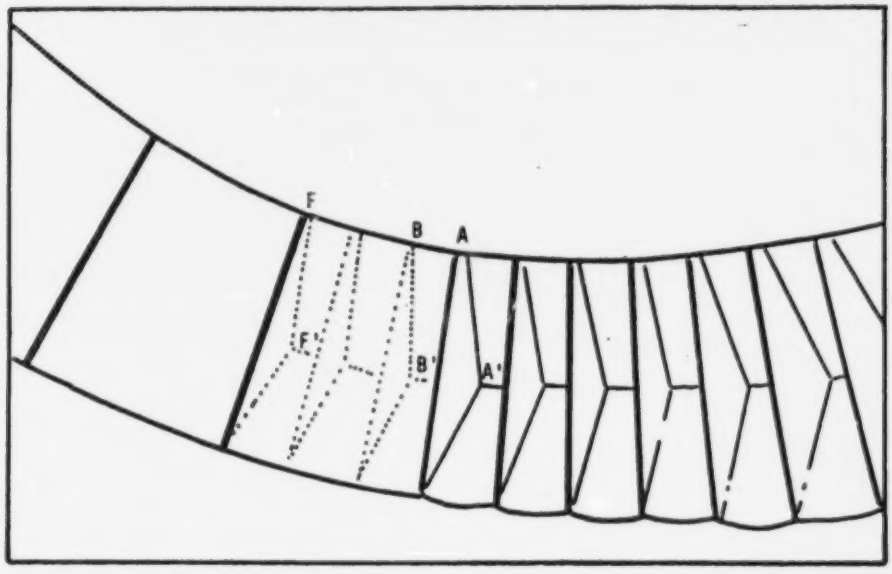


Figure 8 Identification Diagram

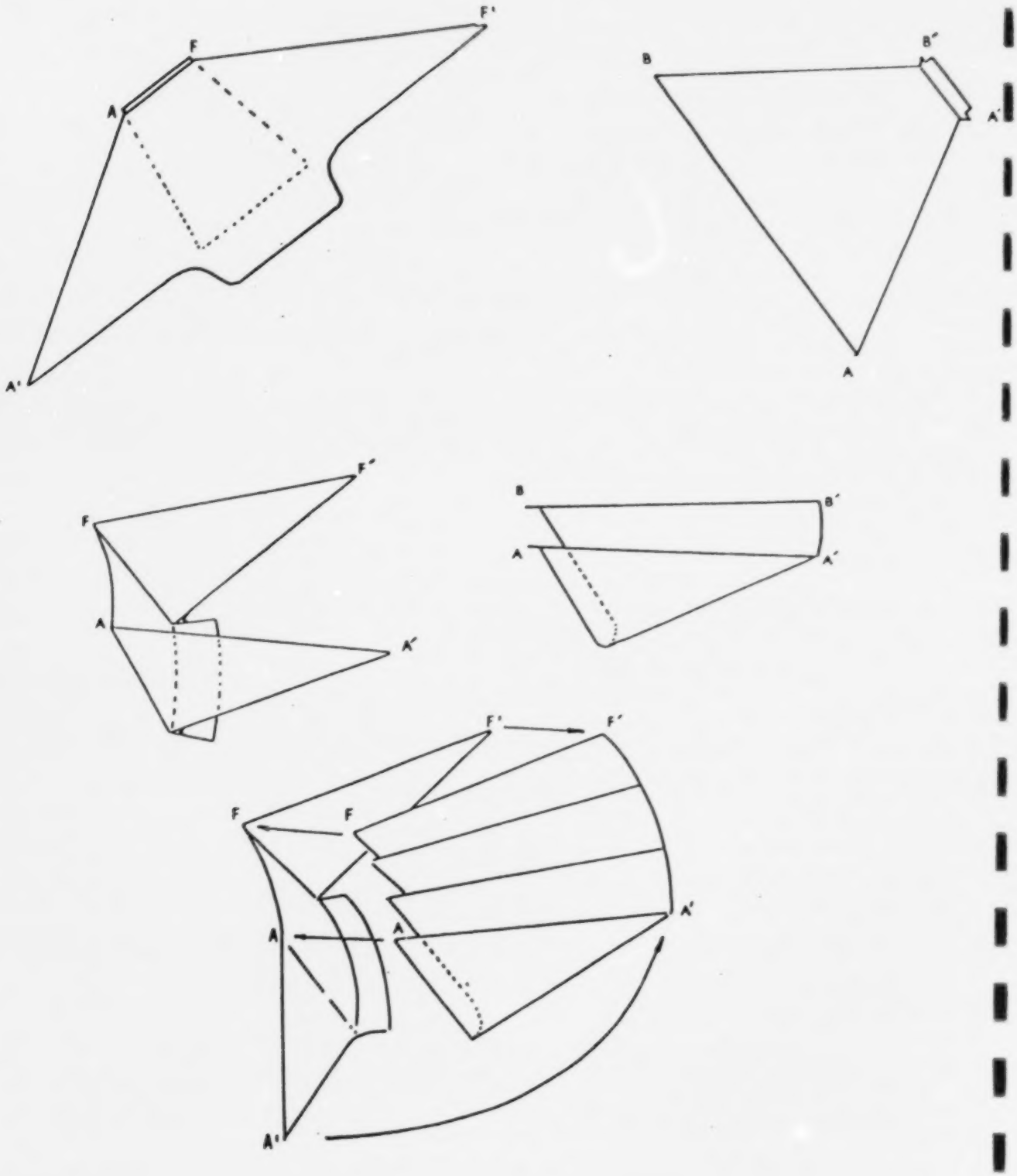


Figure 9 Drag Sheet Assembly Sketches

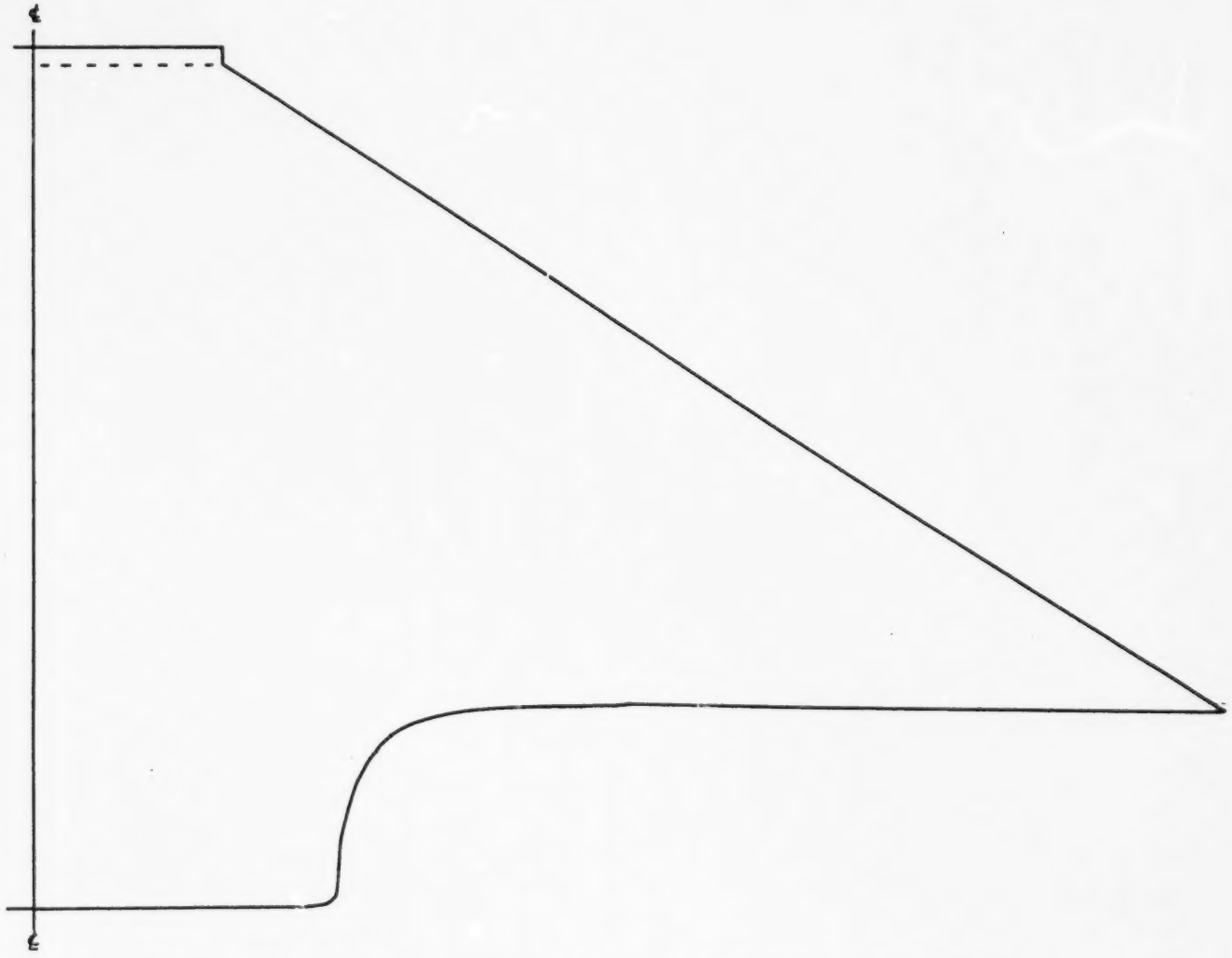


Figure 10 Drag Sheet - Half View of Symmetrical Shape

Figure 11 Segments and Drag Sheets from Outside

Figure 12 Simulated "Scooping" Ice Lumps

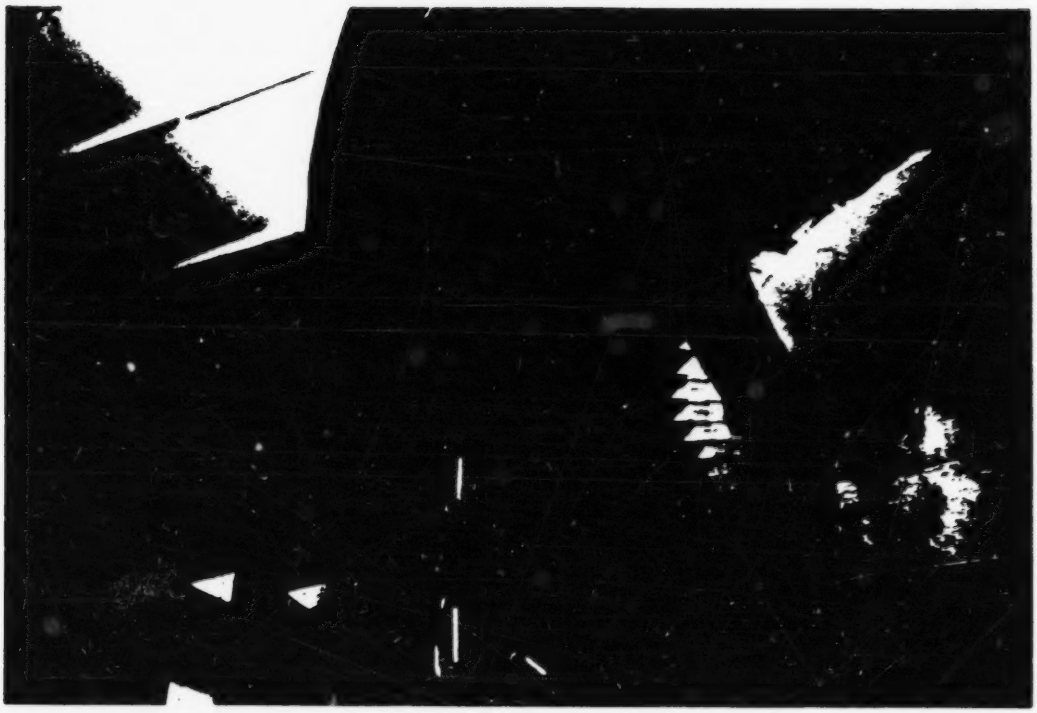


Figure 13 Inflated Segments and Spray Skirts from Underside

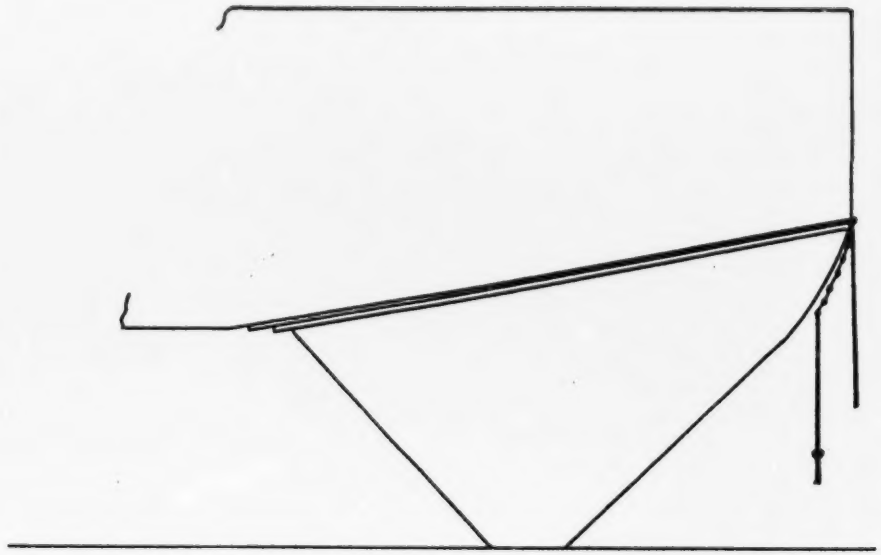


Figure 14 Platform Cross Section
Showing Inflated Skirt Segment and Spray Skirts

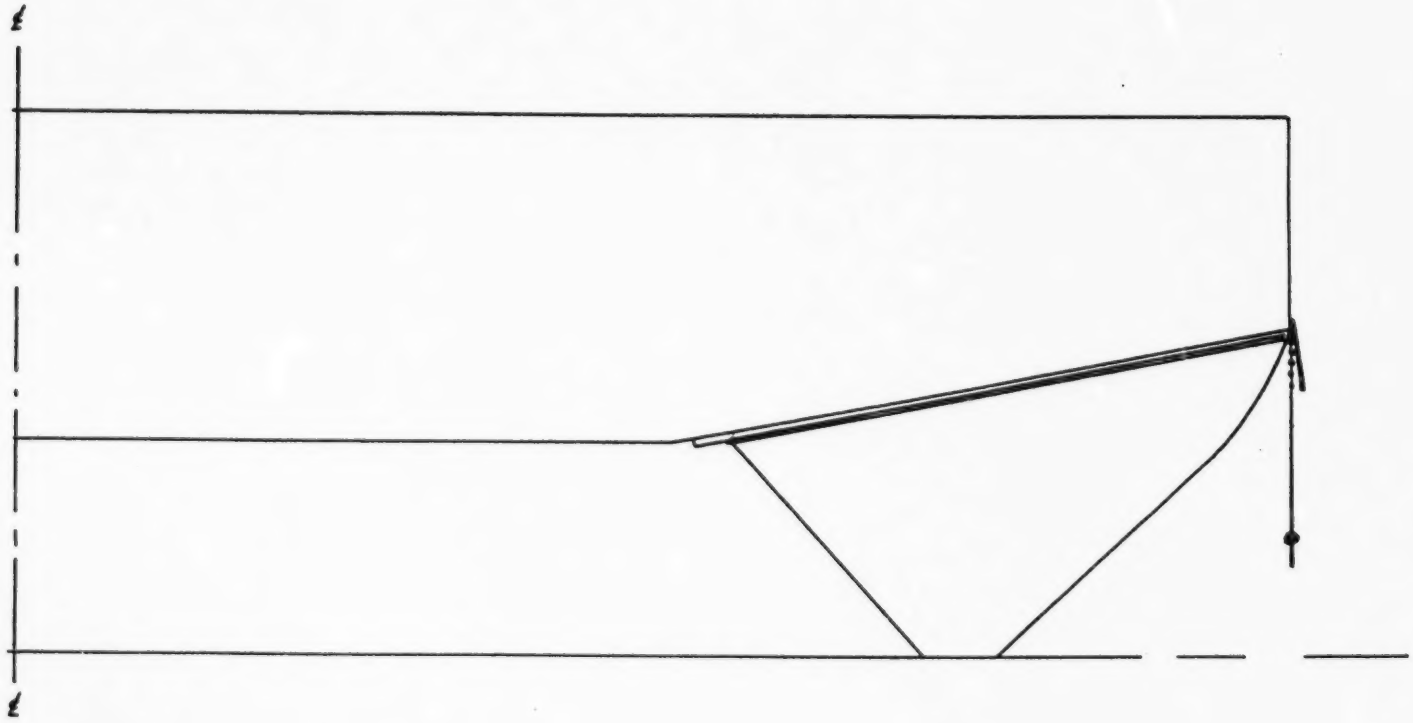
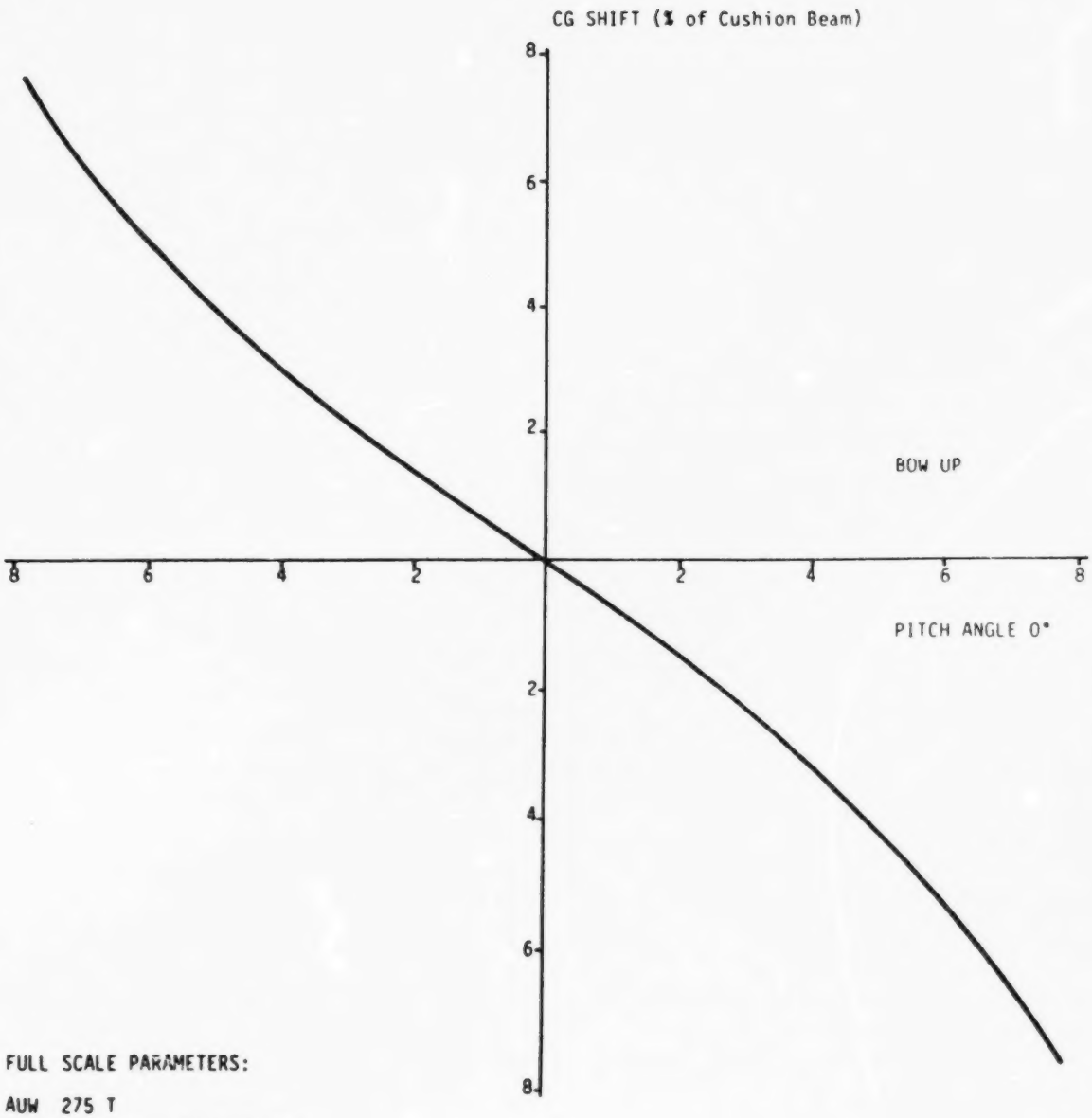


Figure 15 Alternative Spray Skirt Arrangement



FULL SCALE PARAMETERS:

AUW 275 T
CG 1.6 m above bottom skin
Air Flow 109 m^3/s

Figure 16 Typical Stiffness Curve

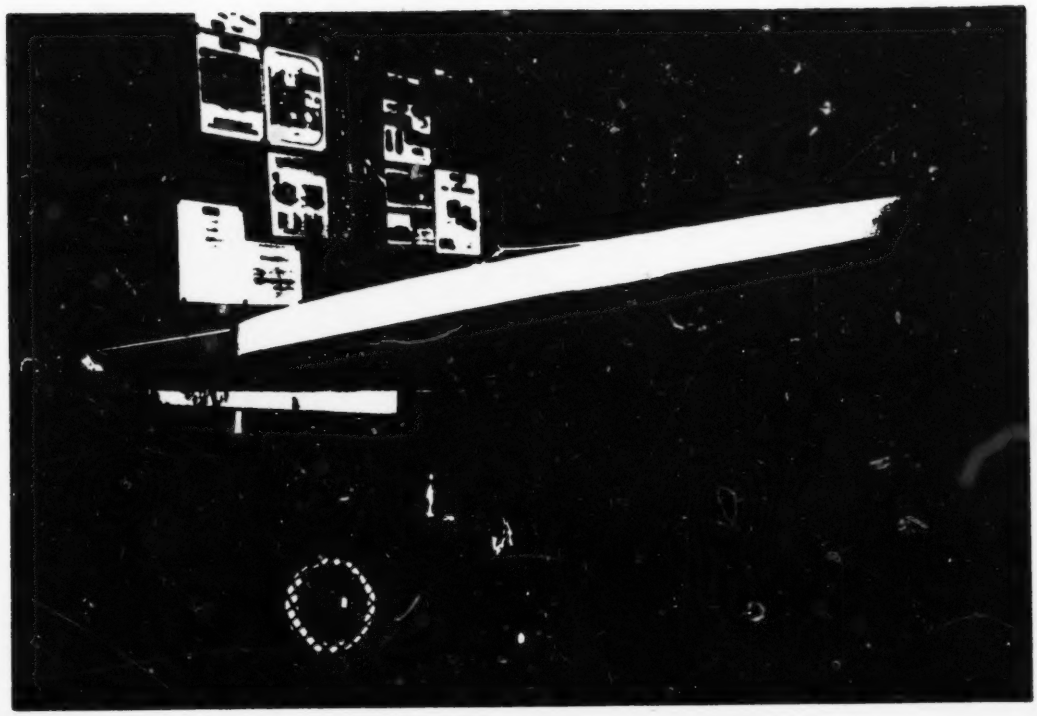


Figure 17 Model with CG Aft

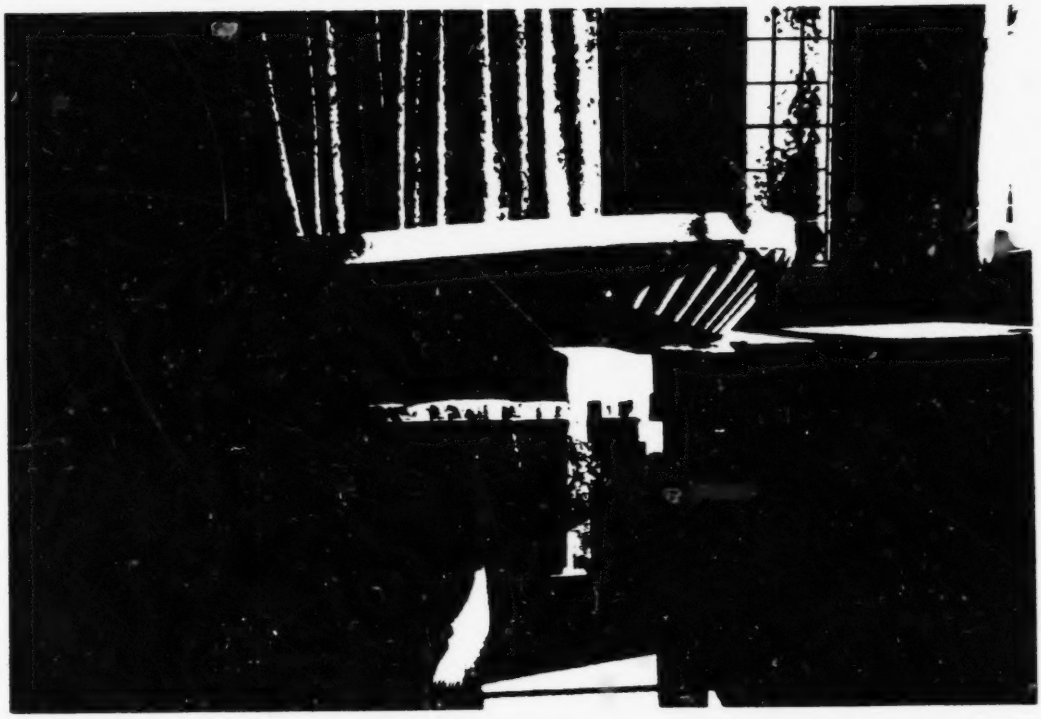


Figure 18 Model Over Simulated Ice Step

APPENDIX 3

COST ESTIMATE BREAKDOWN

INLAND WATERS ACIB COST BREAKDOWN

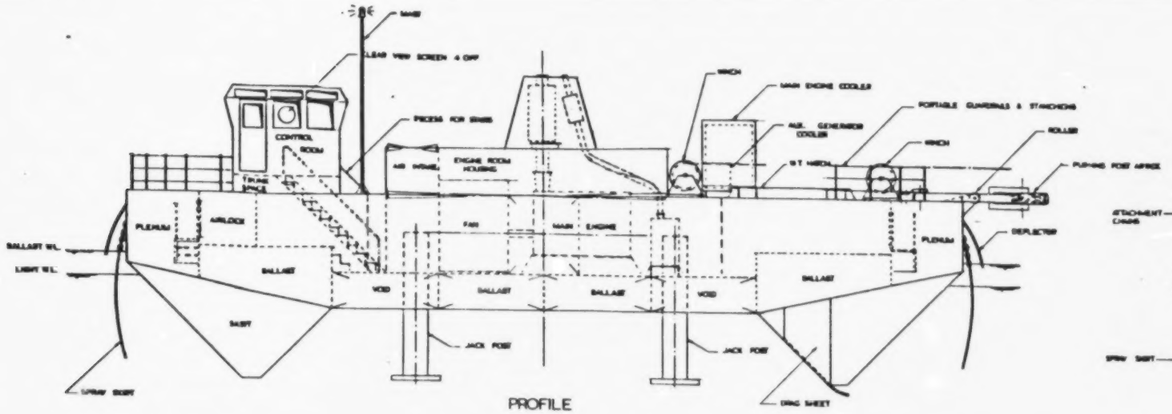
SYSTEM	MATERIAL COST	LABOUR COST	TOTAL
Main engines, fans and generators	535,000.00	95,000.00	630,000.00
Auxiliary generator and machinery	245,000.00	103,000.00	348,000.00
Hull steelwork	144,000.00	800,000.00	944,000.00
Coatings & insulation	80,000.00	67,000.00	147,000.00
Hull fittings (including pushing point)	65,000.00	55,000.00	120,000.00
Electrical installation including heaters and control system	221,000.00	Included	221,000.00
Skirt system	372,000.00	5,000.00	377,000.00
Jacking system	90,000.00	30,000.00	120,000.00
Winches & cables	255,000.00	--	255,000.00
TOTAL COST			3,162,000.00

MID-ARCTIC ACIB COST BREAKDOWN

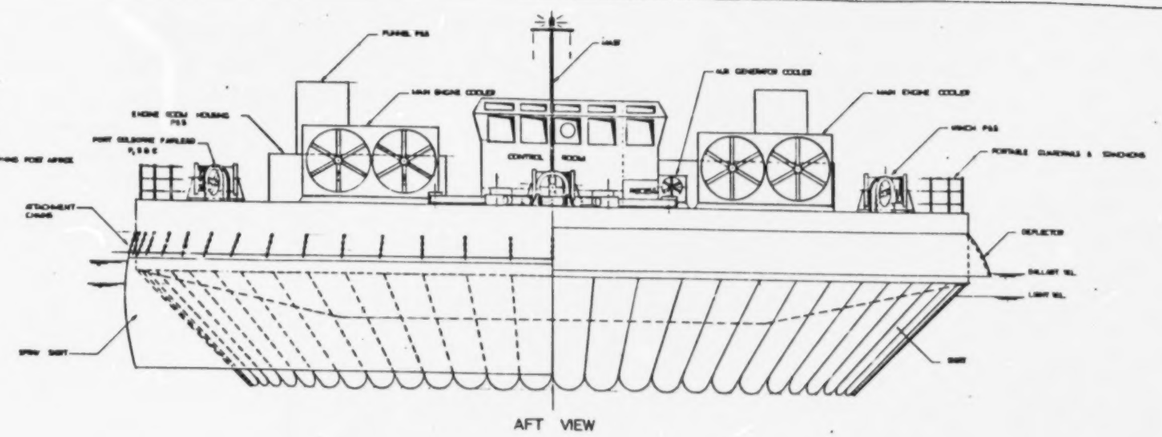
SYSTEM	MATERIAL COST	LABOUR COST	TOTAL
Main engines, fans and generators	1,664,000.00	190,000.00	1,854,000.00
Auxiliary generator and machinery	330,000.00	155,000.00	485,000.00
Hull steelwork	442,000.00	2,640,000.00	3,082,000.00
Coatings & insulation	237,000.00	354,000.00	591,000.00
Hull fittings	93,000.00	60,000.00	153,000.00
Electrical installation including heaters and control system	298,000.00	Included	298,000.00
Skirt system	324,000.00	5,000.00	329,000.00
Winches & cables	300,000.00	--	300,000.00
TOTAL COST			7,092,000.00

APPENDIX 4

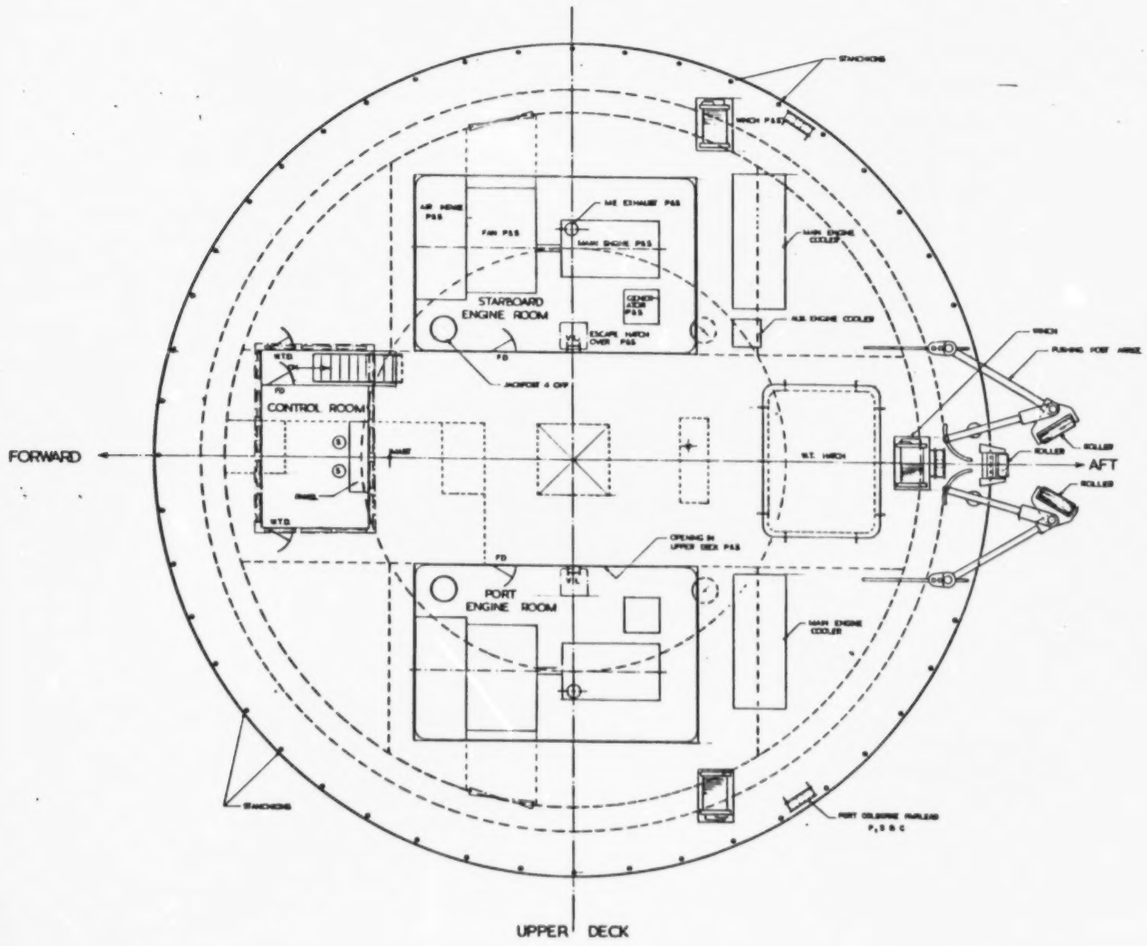
CONCEPT DESIGN DRAWINGS



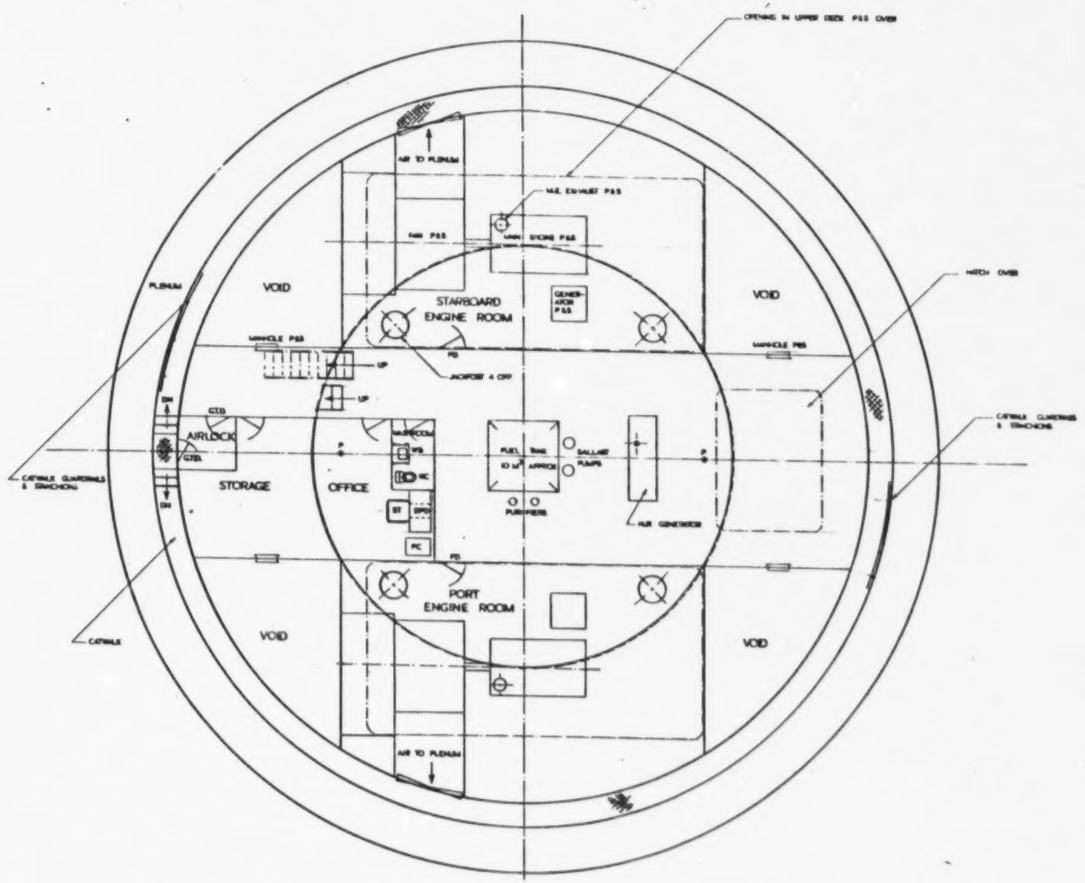
PROFILE



AFT VIEW



UPPER DECK



LOWER DECK

CRAFT PARTICULARS

OUTSIDE DIAMETER	23·6 m
CUSHION DIAMETER	17·5 m
MAXIMUM WEIGHT	275 t
LIGHT WEIGHT	190 t
MAXIMUM CUSHION PRESSURE	11 kPa
INSTALLED POWER	2350 kW
LIFT POWER	1500 kW
ENDURANCE	12 hours

LEGEND

D.P.D.	DOUBLE PEDESTAL DESK
F.C.	FILING CABINET
F.D.	FIRE DOOR
G.T.D.	GAS TIGHT DOOR
P.	PILLAR
S.	STOOL
S.T.	SWIVEL TILTER DESK CHAIR
V.L.	VERTICAL LADDER
W.B.	WASH BASIN
W.C.	WATER CLOSET
W.T.D.	WATERTIGHT DOOR

NO.	REVISIONS
APPROVALS	
DATE	

german & milne inc.
Marine Transportation Consultants
Naval Architects
Montreal Ottawa Vancouver

CLIENT: TRANSPORTATION DEVELOPMENT CENTRE

PROJECT: INLAND WATERS A.C.I.B.

TITLE: GENERAL ARRANGEMENT

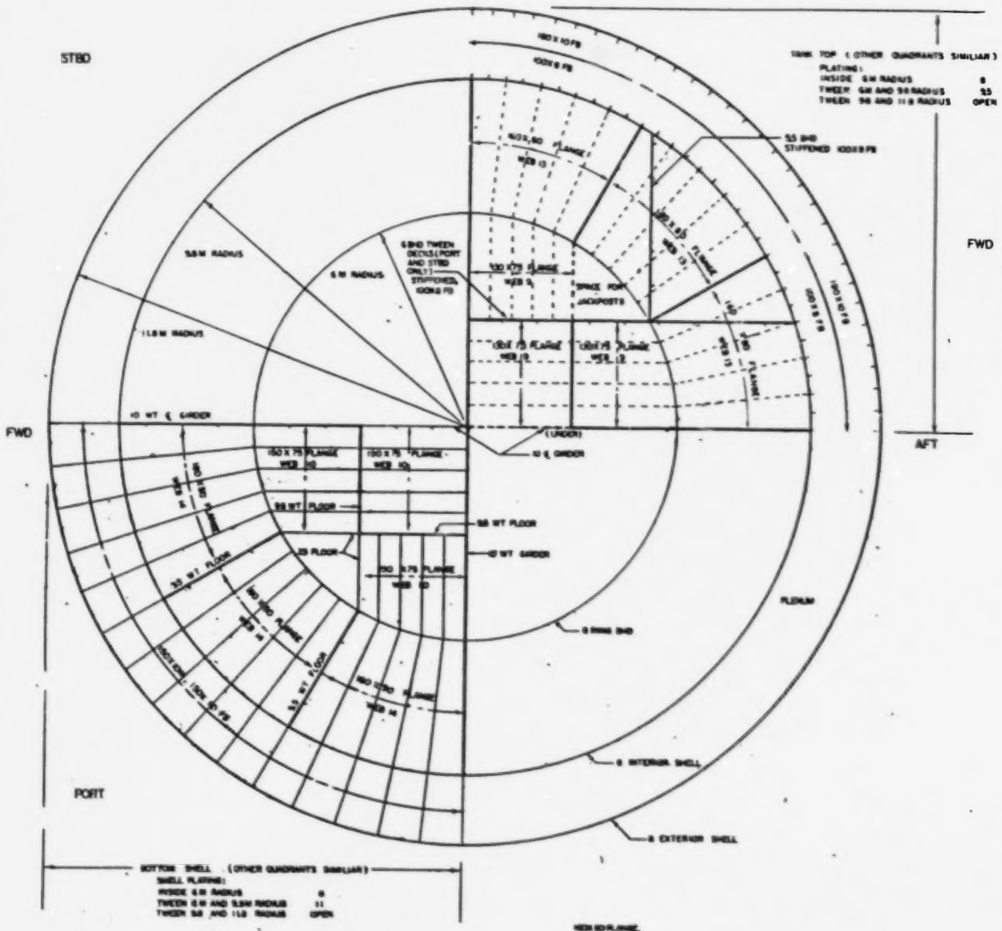
SCALE: 1/8"

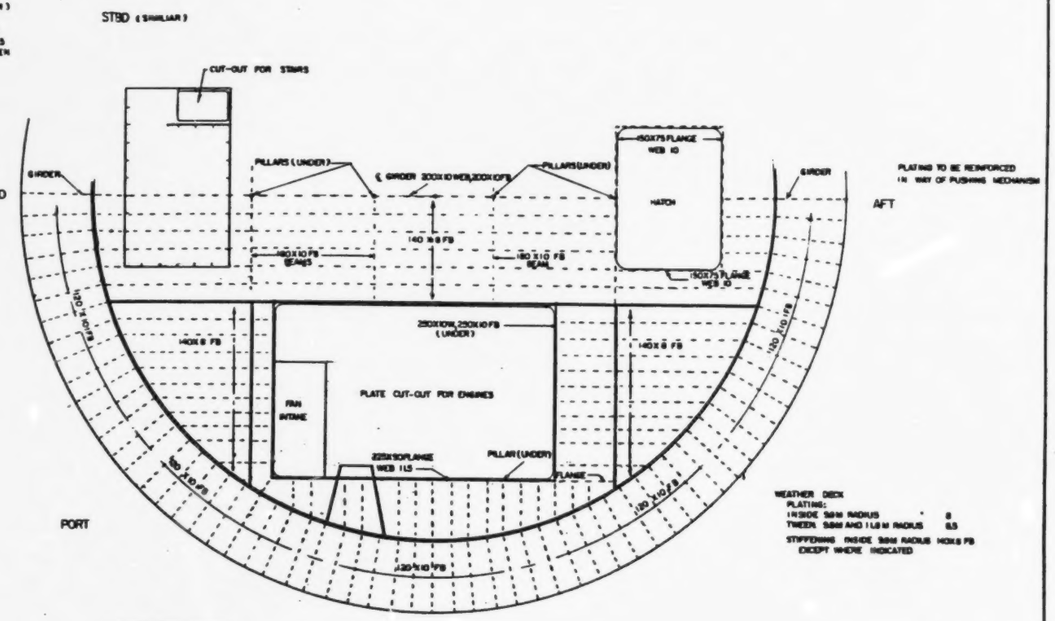
DRAWN BY: G. Baillie

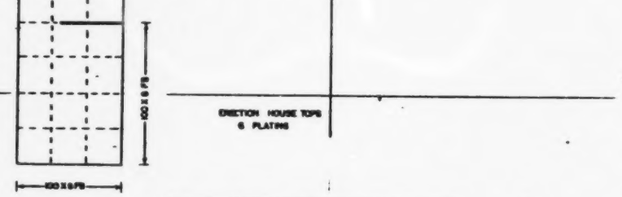
CHECKED BY: B. GILLESPIE

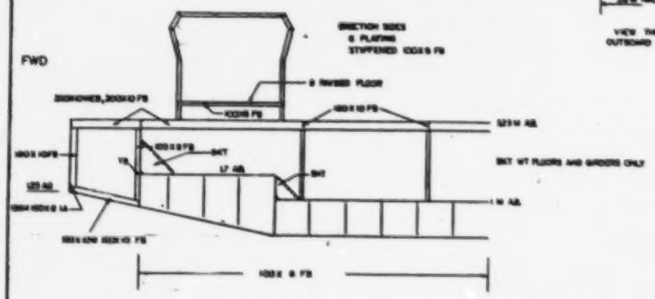
DRG. NO. 1-710-101

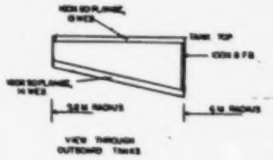
SHEET NO. 1 OF 1

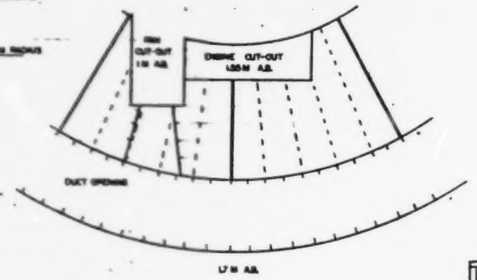




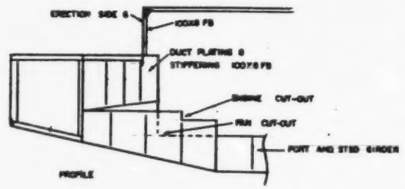








DUCT DETAIL TWEEN 6 AND 9.6M RADIUS PORT AND STBD



NO	REVISIONS	DATE
APPROVALS		
DATE		

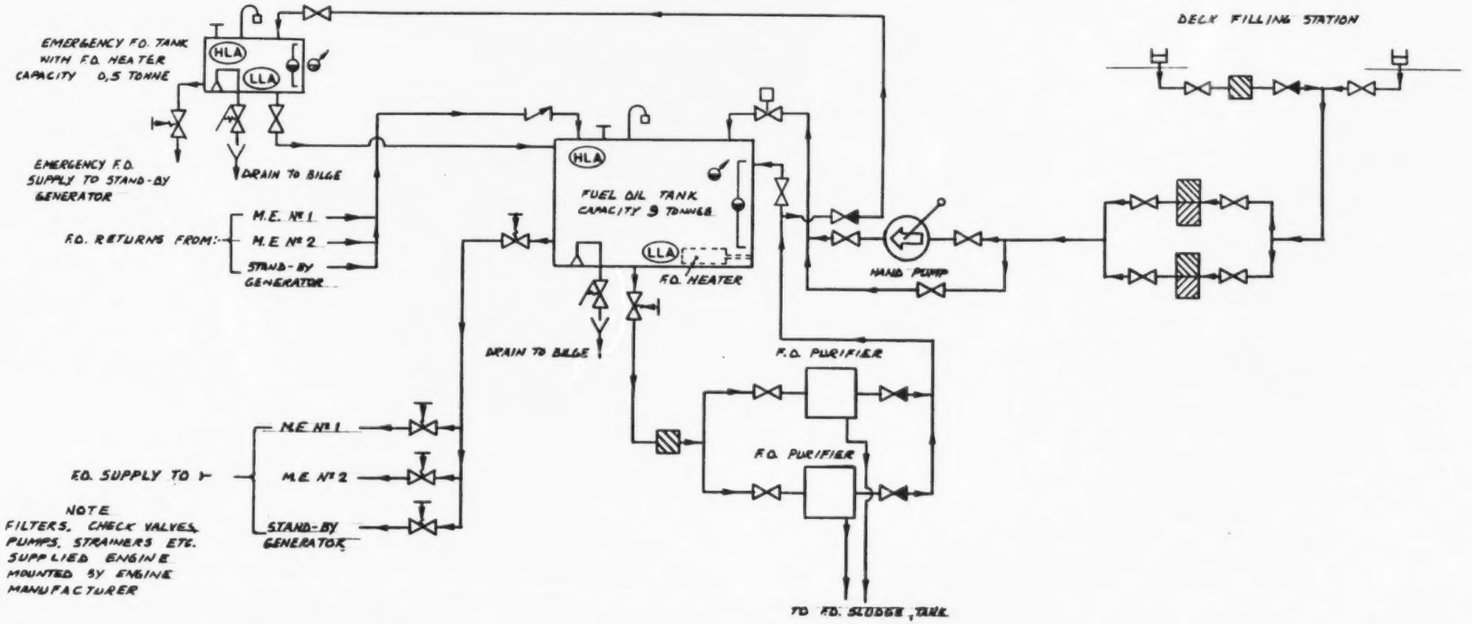
german & milne inc.
Marine Transportation Consultants
Naval Architects
Montreal Ottawa Vancouver

CLIENT TRANSPORTATION DEVELOPMENT CENTRE

PROJECT INLAND WATERS ACIB
CONCEPTUAL DESIGN

TITLE STRUCTURAL ARRANGEMENT

SCALE 1:50 | DATE JULY
DRAWN BY A.S. MALONEY
CHECKED BY
DWG. NO 1-7113-102 | REV. | SHEET NO 1 OF 1



LEGEND

- GLOBE VALVE
- GLOBE VALVE S.D.N.R.
- CHECK VALVE
- QUICK CLOSE, FIRE SAFE VALVE
- SELF CLOSING DRAIN VALVE
- REMOTE OPERATED VALVE
- FILTER
- DUPLEX FILTER
- LEVEL INDICATOR
- REMOTE LEVEL INDICATOR
- HLA HIGH LEVEL ALARM
- LLA LOW LEVEL ALARM
- VENT FITTED WITH ANTI-FLASH GUARD
- T SOUNDING PIPE

NO	REVISIONS	DATE
APPROVALS		
DATE		

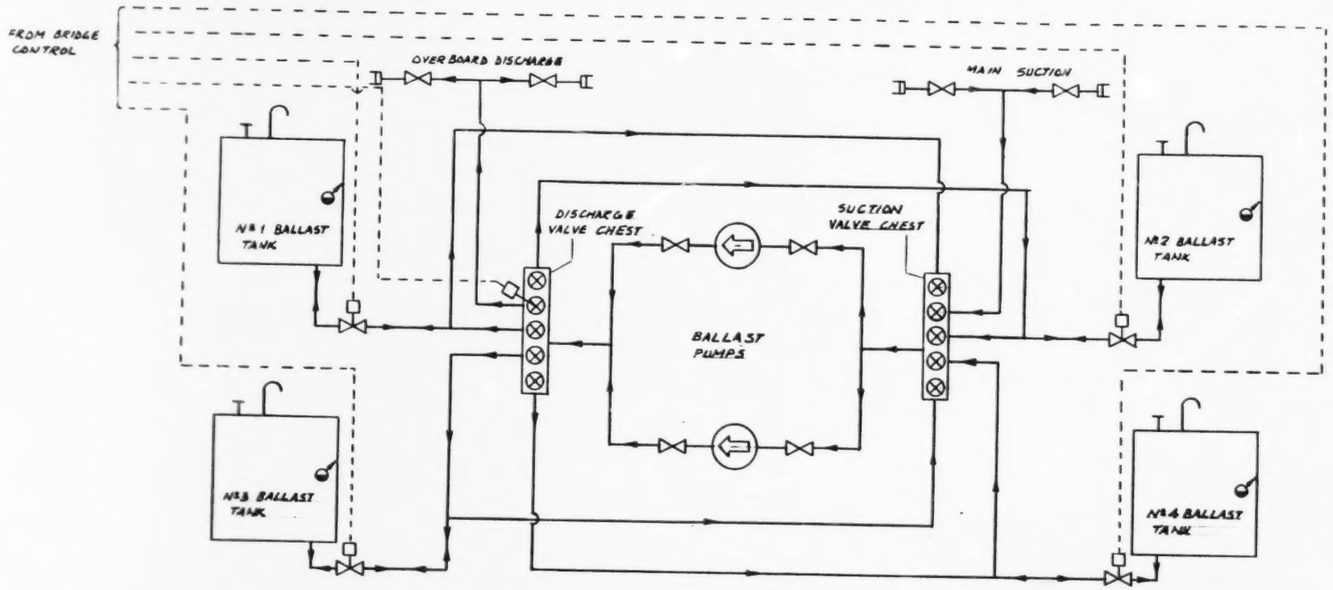
german & milne inc.
Marine Transportation Consultants
Naval Architects
Montreal Ottawa Vancouver

CLIENT
TRANSPORTATION DEVELOPMENT CENTRE

PROJECT
INLAND WATERS A C I B

TITLE
FUEL OIL SYSTEM DIAGRAMMATIC

SCALE: N/A DATE: JUNE '84
DRAWN BY: M J SHILLITO
CHECKED BY: L. EMSLEY
DRG. NO 1-7113-201 REV.
SHEET NO 1 OF 1



LEGEND

- GLOBE VALVE
- REMOTE OPERATED VALVE
- REMOTE LEVEL INDICATOR
- VENT PIPE
- T SOUNDING PIPE
- VALVE CHEST S.D.S.L.

NOTE

MID-ARCTIC A C I B CONCEPT HAS FOUR BALLAST TANKS (AS DRAWN). INLAND WATER A C I B CONCEPT IS SIMILAR BUT HAS FIVE BALLAST TANKS

NO	REVISIONS	DATE
APPROVALS		
DATE		

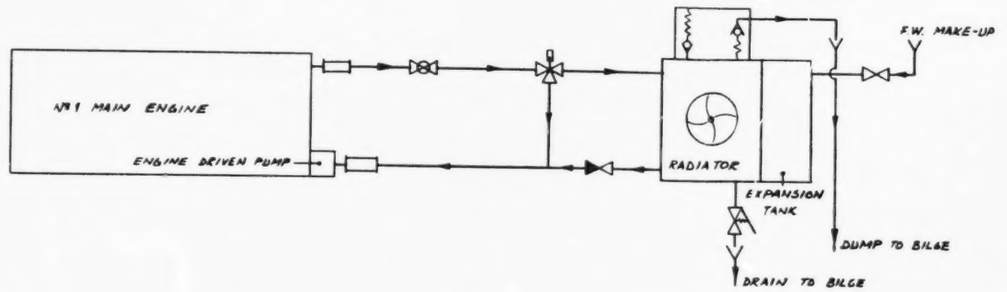
german & milne inc.
Marine Transportation Consultants
Naval Architects
Montreal Ottawa Vancouver

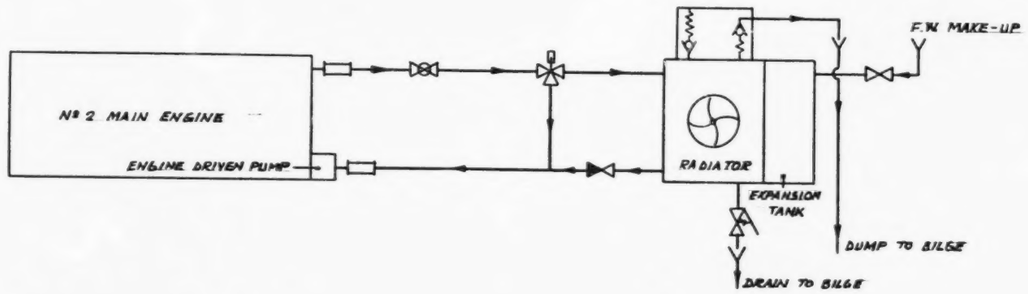
CLIENT: TRANSPORTATION DEVELOPMENT CENTRE

PROJECT: INLAND WATERS ACIB AND MID ARCTIC ACIB

TITLE: BALLAST SYSTEM DIAGRAMMATIC

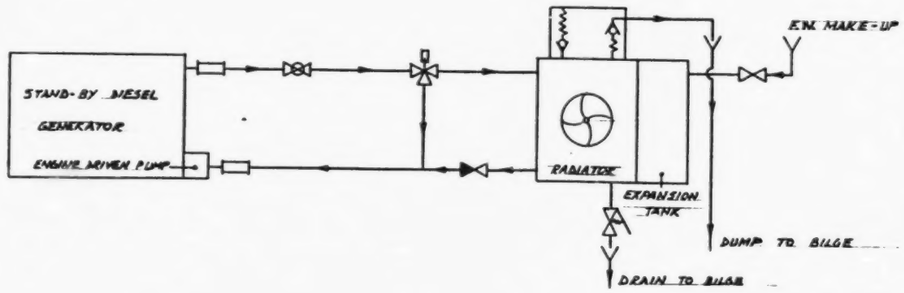
SCALE: N/A | DATE: JUNE '84
DRAWN BY: M J SHILLITO
CHECKED BY: L EMSLEY
DRG. NO: 1-7113-202 | REV. | SHEET NO 1 OF 1





LEGEND

- GLOBE VALVE
- GLOBE VALVE S.B.N.R.
- BUTTERFLY VALVE
- TEMPERATURE CONTROL VALVE
- SELF CLOSING DRAIN VALVE
- FLEXIBLE CONNECTION



NO	REVISIONS	DATE
APPROVALS		
DATE		

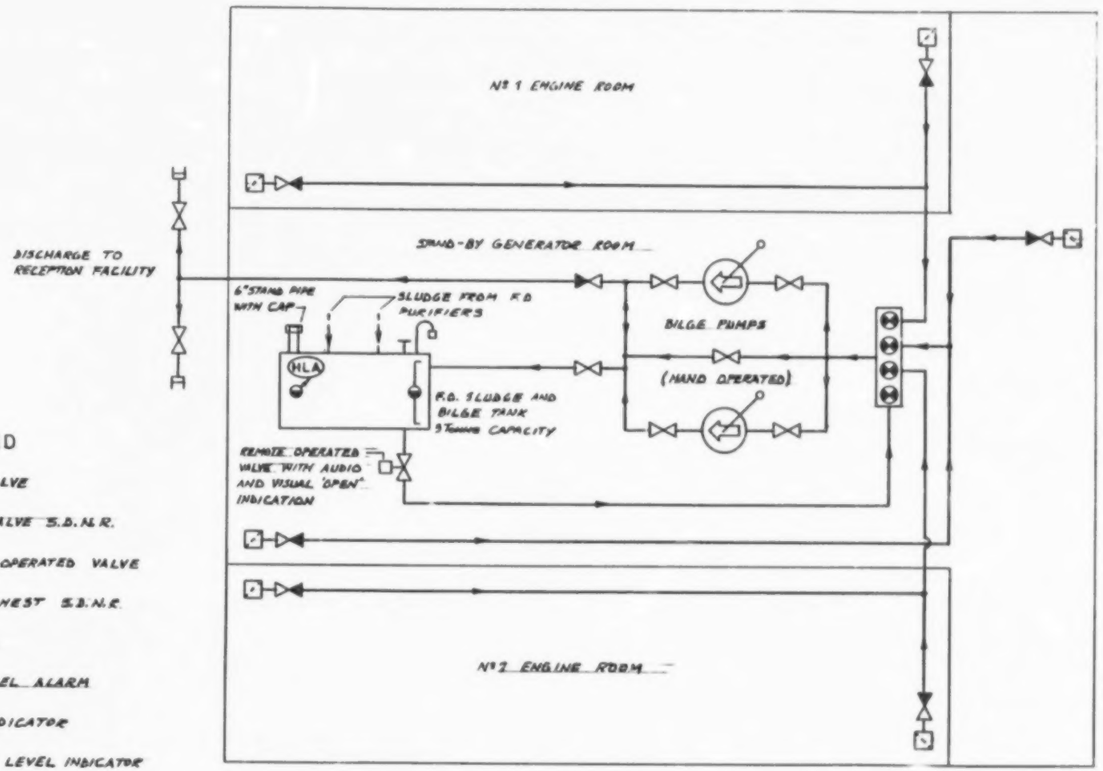
german & milne inc.
Marine Transportation Consultants
Naval Architects
Montreal Ottawa Vancouver

CLIENT
TRANSPORTATION DEVELOPMENT CENTRE

PROJECT
INLAND WATERS A C I B

TITLE
COOLING WATER DIAGRAMMATIC

SCALE: N/A	DATE: JUNE '84
DRAWN BY: M J SHILLITO	
CHECKED BY: L EMSLEY	
DRG. NO. 1-7113-203 REV.	SHEET NO 1 OF 1



LEGEND

- GLOBE VALVE
- GLOBE VALVE S.D.N.R.
- REMOTE OPERATED VALVE
- VALVE CHEST S.D.N.R.
- MUD BOX.
- HLA HIGH LEVEL ALARM
- LEVEL INDICATOR
- REMOTE LEVEL INDICATOR
- VENT FITTED WITH ANTI-FLASH GUARD
- T SOUNDING PIPE

NO	REVISIONS	DATE
APPROVALS		
DATE		

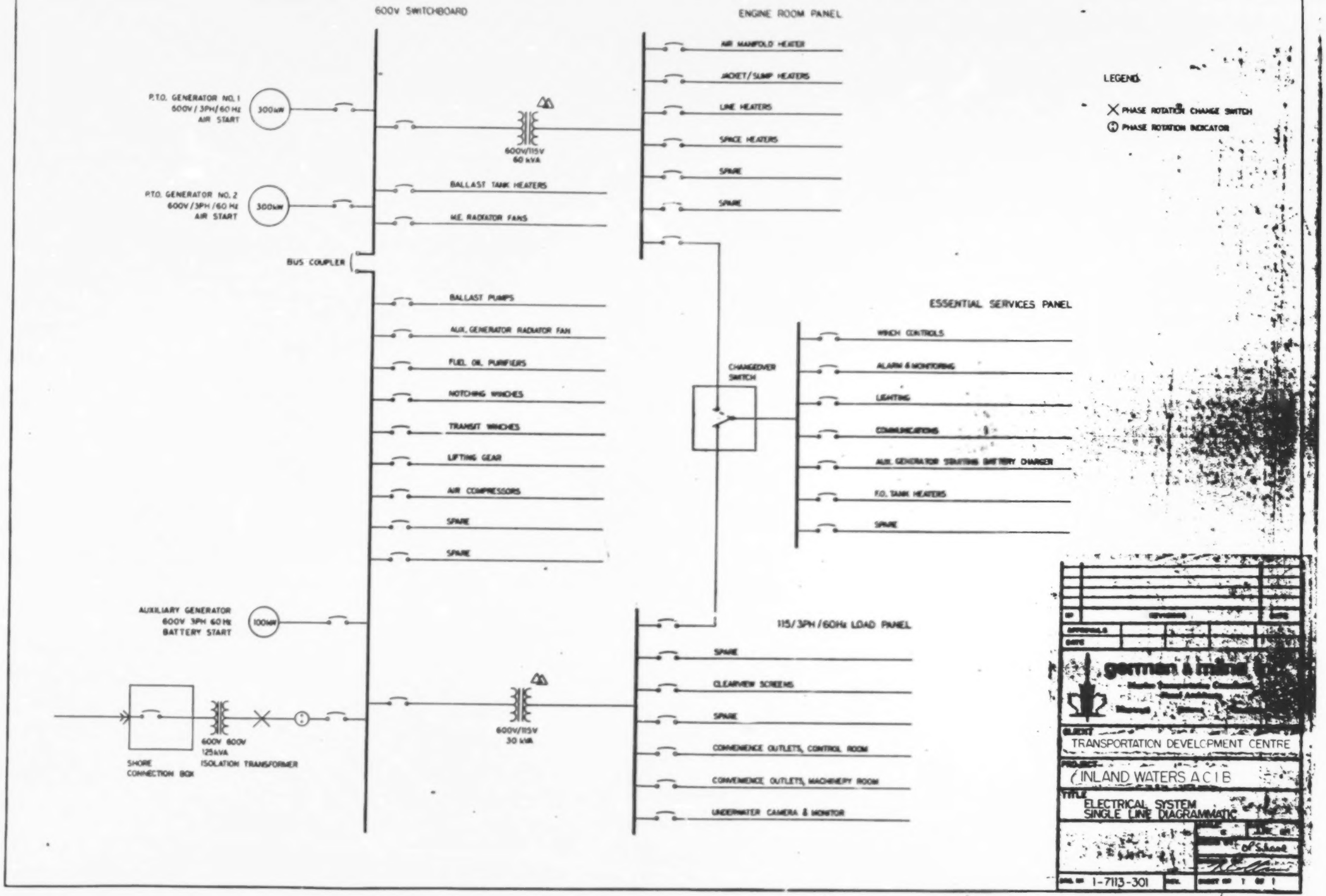
german & milne inc.
Marine Transportation Consultants
Naval Architects
Montreal Ottawa Vancouver

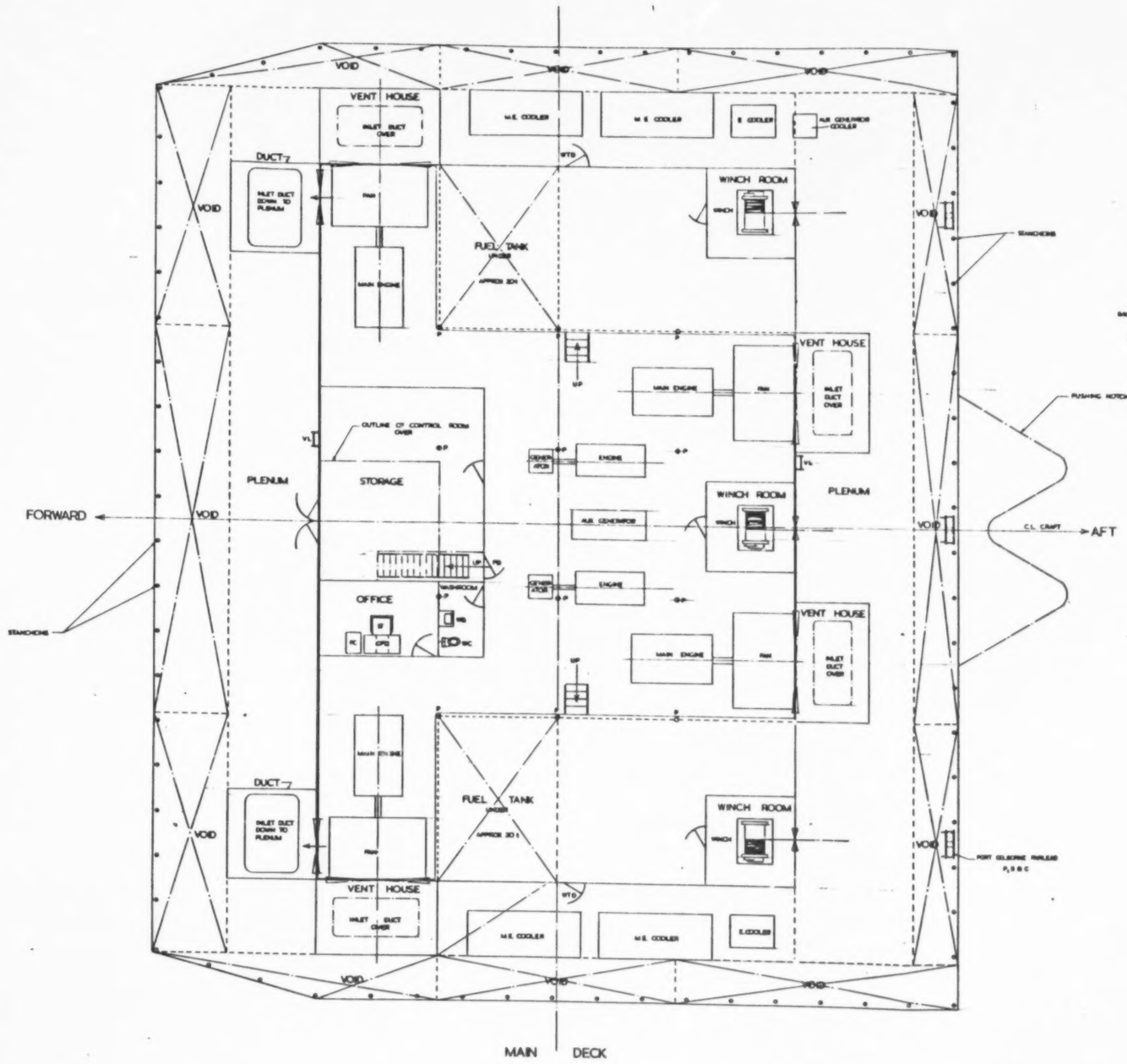
CLIENT
TRANSPORTATION DEVELOPMENT CENTRE

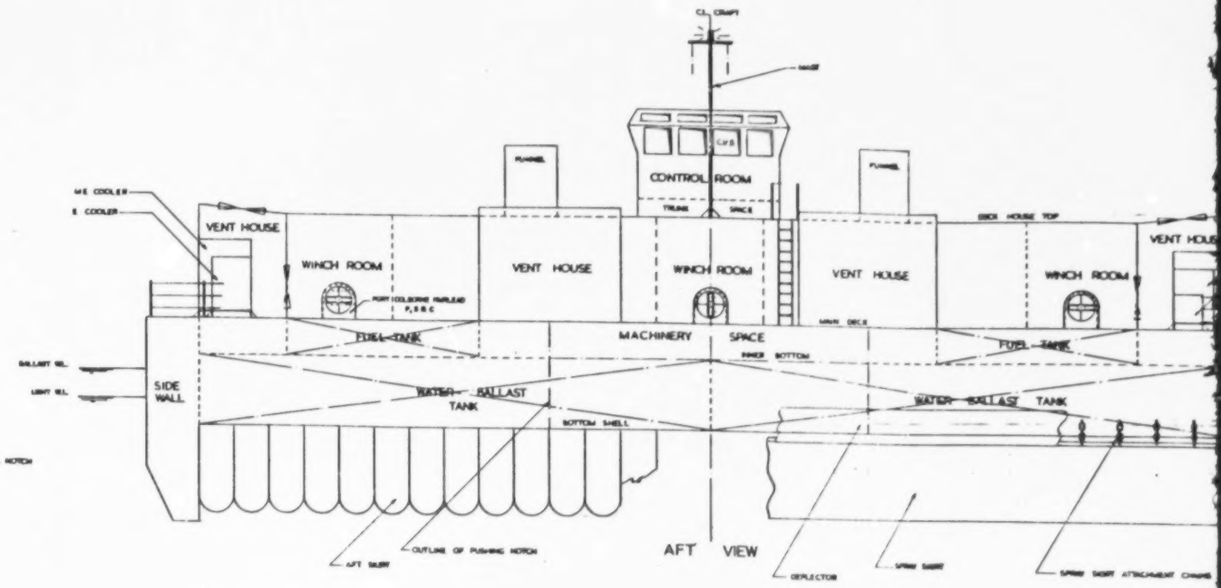
PROJECT
INLAND WATERS AC1B

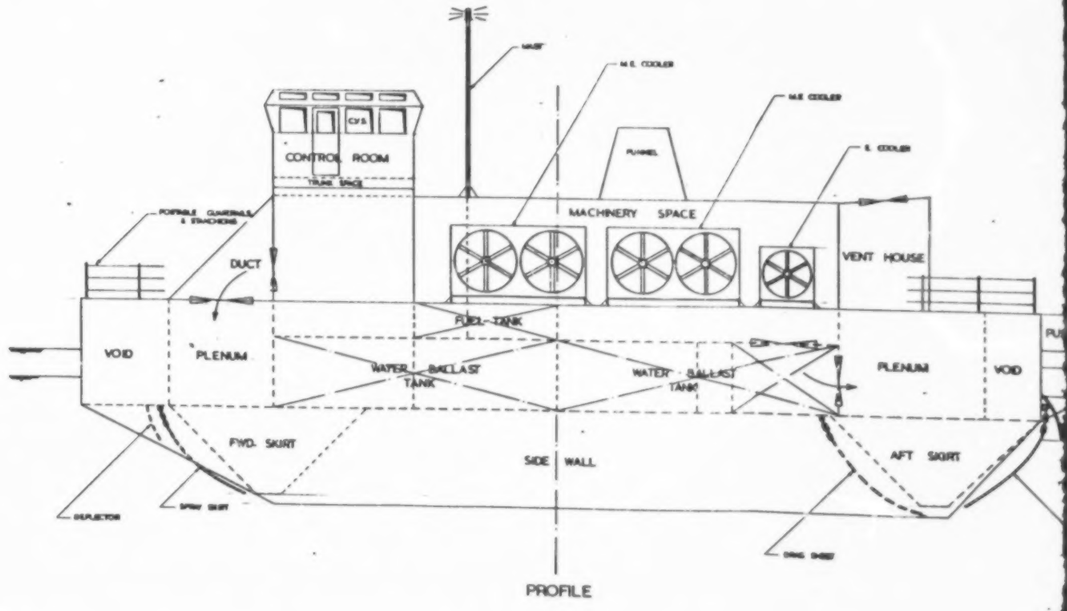
TITLE
BILGE SYSTEM DIAGRAMMATIC

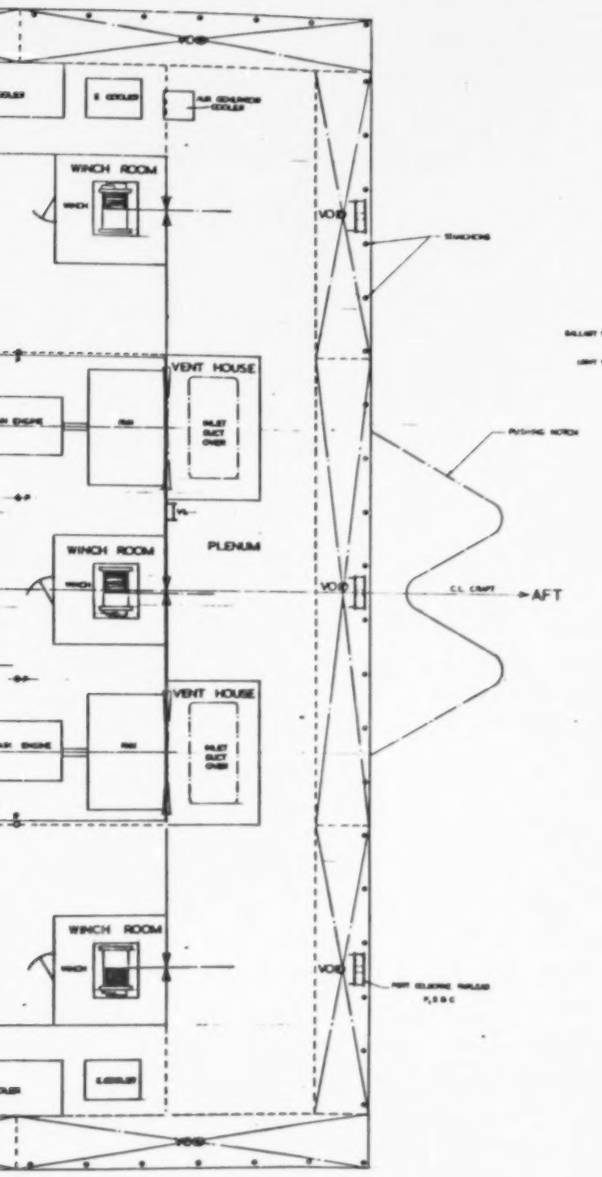
SCALE: N/A
DATE: JUNE '84
DRAWN BY: M.J.SHILLITO
CHECKED BY: C.EMSLEY
DRG. NO 1-7113-204 REV.
SHEET NO 1 OF 1

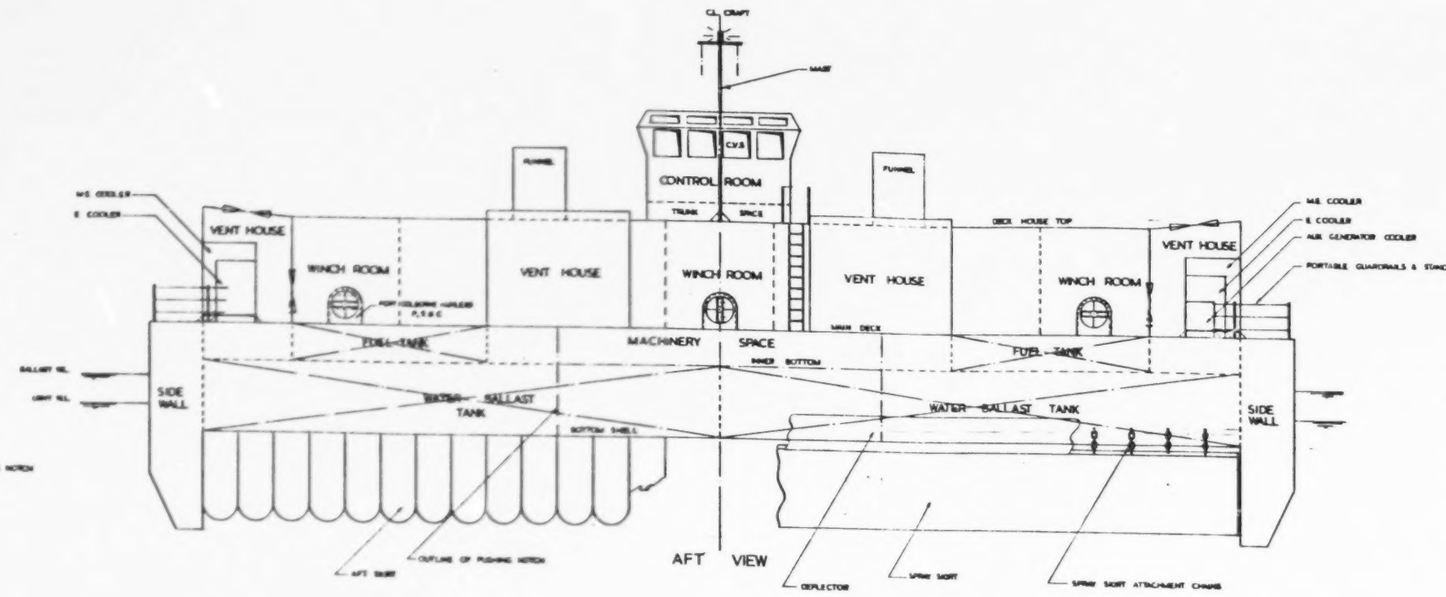

600v SWITCHBOARD
ENGINE ROOM PANEL
P.T.O. GENERATOR NO. 1
600V / 3PH / 60 Hz
AIR START
300kW
P.T.O. GENERATOR NO. 2
600V / 3PH / 60 Hz
AIR START
300kW
600V/115V
60 kVA
AIR MANIFOLD HEATER
JACKET/SUMP HEATERS
LINE HEATERS
SPACE HEATERS
SPARE
SPARE
BALLAST TANK HEATERS
M.E. RADIATOR FANS
BUS COUPLER
BALLAST PUMPS
AUX. GENERATOR RADIATOR FAN
FUEL OIL PURIFIERS
MOORING WINCHES
TRANSIT WINCHES
LIFTING GEAR
AIR COMPRESSORS
SPARE
SPARE
CHANGEOVER SWITCH
ESSENTIAL SERVICES PANEL
WINCH CONTROLS
ALARM & MONITORING
LIGHTING
COMMUNICATIONS
AUX. GENERATOR STARTING BATTERY CHARGER
F.O. TANK HEATERS
SPARE
AUXILIARY GENERATOR
600V 3PH 60 Hz
BATTERY START
100kW
SHORE CONNECTION BOX
600V 600V
125kVA
ISOLATION TRANSFORMER
600V/115V
30 kVA
115/3PH/60Hz LOAD PANEL
SPARE
CLEARVIEW SCREENS
SPARE
CONVENIENCE OUTLETS, CONTROL ROOM
CONVENIENCE OUTLETS, MACHINERY ROOM
UNDERWATER CAMERA & MONITOR
LEGEND
PHASE ROTATION CHANGE SWITCH
PHASE ROTATION INDICATOR
BY
REVISIONS
APPROVALS
DATE
CLIENT
TRANSPORTATION DEVELOPMENT CENTRE
PROJECT
INLAND WATERS A C I B
TITLE
ELECTRICAL SYSTEM
SINGLE LINE DIAGRAMMATIC
DWG. NO. 1-7113-301
REV.
SHEET NO. 1 OF 1

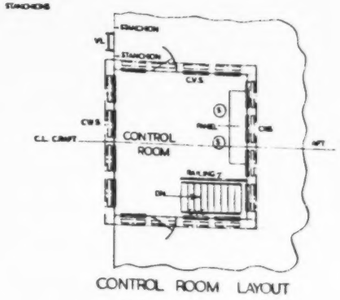

VOID
VENT HOUSE
INLET DUCT OVER
M.E. COOLER
M.E. COOLER
E COOLER
AUX GENERATOR COOLER
DUCT
INLET DUCT DOWN TO PLENUM
FAN
WTD
WINCH ROOM
WINCH
FUEL TANK
UNDER
APPROX 20 t
MAIN ENGINE
STANCHIONS
UP
VENT HOUSE
MAIN ENGINE
FAN
INLET DUCT OVER
PUSHING NOTCH
VL
OUTLINE OF CONTROL ROOM OVER
PLENUM
STORAGE
GENERATOR
ENGINE
WINCH ROOM
WINCH
PLENUM
FORWARD
VOID
AUX GENERATOR
C.L. CRAFT
AFT
OFFICE
WASHROOM
GPO
WC
ENGINE
GENERATOR
VENT HOUSE
MAIN ENGINE
FAN
INLET DUCT OVER
STANCHIONS
MAIN ENGINE
DUCT
INLET DUCT DOWN TO PLENUM
FAN
FUEL TANK
UNDER
APPROX 20 t
WINCH ROOM
WINCH
VOID
PORT GILBORNE PARELOAD P, S & C
VENT HOUSE
INLET DUCT OVER
WTD
M.E. COOLER
M.E. COOLER
E.COOLER
VOID
VOID
VOID
MAIN DECK


C.L. CRAFT
MAST
M.E. COOLER
E COOLER
VENT HOUSE
CONTROL ROOM
CAB
TRUNK SPACE
FUNNEL
WINCH ROOM
PORTABLE GUARDRAILS & STANCHIONS P, S & C
VENT HOUSE
WINCH ROOM
VENT HOUSE
WINCH ROOM
VENT HOUSE
MAIN DECK
FUEL TANK
MACHINERY SPACE
INNER BOTTOM
FUEL TANK
BALLAST WL
LIGHT WL
SIDE WALL
WATER BALLAST TANK
BOTTOM SHELL
WATER BALLAST TANK
AFT SKIRT
OUTLINE OF PUSHING NOTCH
AFT VIEW
DEFLECTOR
SPRAY SKIRT
SPRAY SKIRT ATTACHMENT CHAINS

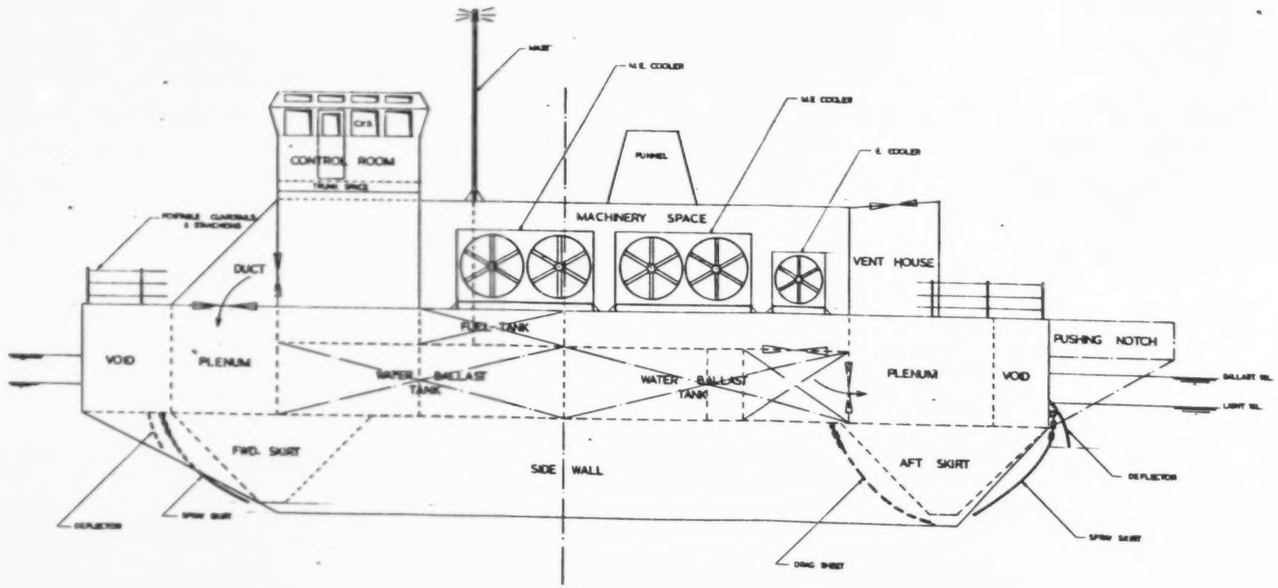

MAST
M.E. COOLER
M.E. COOLER
E. COOLER
C/S
CONTROL ROOM
FUNNEL
TRUNK SPACE
PORTABLE GUARDRAILS & STANCHIONS
MACHINERY SPACE
VENT HOUSE
DUCT
FUEL TANK
VOID
PLENUM
WATER BALLAST TANK
WATER BALLAST TANK
PLENUM
VOID
FWD. SKIRT
SIDE WALL
AFT SKIRT
DEFLECTOR
SPRAY SKIRT
SPRAY SKIRT
PROFILE







CONTROL ROOM LAYOUT



PROFILE

CRAFT PARTICULARS

LENGTH (EXCLUDING PUSHING NOTCH)	27 m
BEAM	32 m
CUSHION LENGTH	19.5 m
CUSHION BEAM	29 m
MAXIMUM WEIGHT	1200 t
LIGHT WEIGHT	600 t
MAXIMUM CUSHION PRESSURE	20 kPa
INSTALLED POWER	5725 kW
LIFT POWER	5100 kW
ENDURANCE	24 hours

LEGEND

C.V.S.	CLEAR VIEW SCREEN
D.P.D.	DOUBLE PEDESTAL DESK
F.C.	FILING CABINET
F.D.	FIRE DOOR
G.T.D.	GASTIGHT DOOR
P.	PILLAR
S.	STOOL
S.I.	SWIVEL TILTER DESK CHAIR
V.L.	VERTICAL LADDER
W.B.	WASH BASIN
W.C.	WATER CLOSET
W.T.D.	WATERTIGHT DOOR

NO	REVISIONS	DATE	
APPROVALS			
DATE			

german & milne inc.
Marine Transportation Consultants
Naval Architects
Montreal Ottawa Vancouver

CLIENT: TRANSPORTATION DEVELOPMENT CENTRE

PROJECT: MID-ARCTIC A.C.I.B.

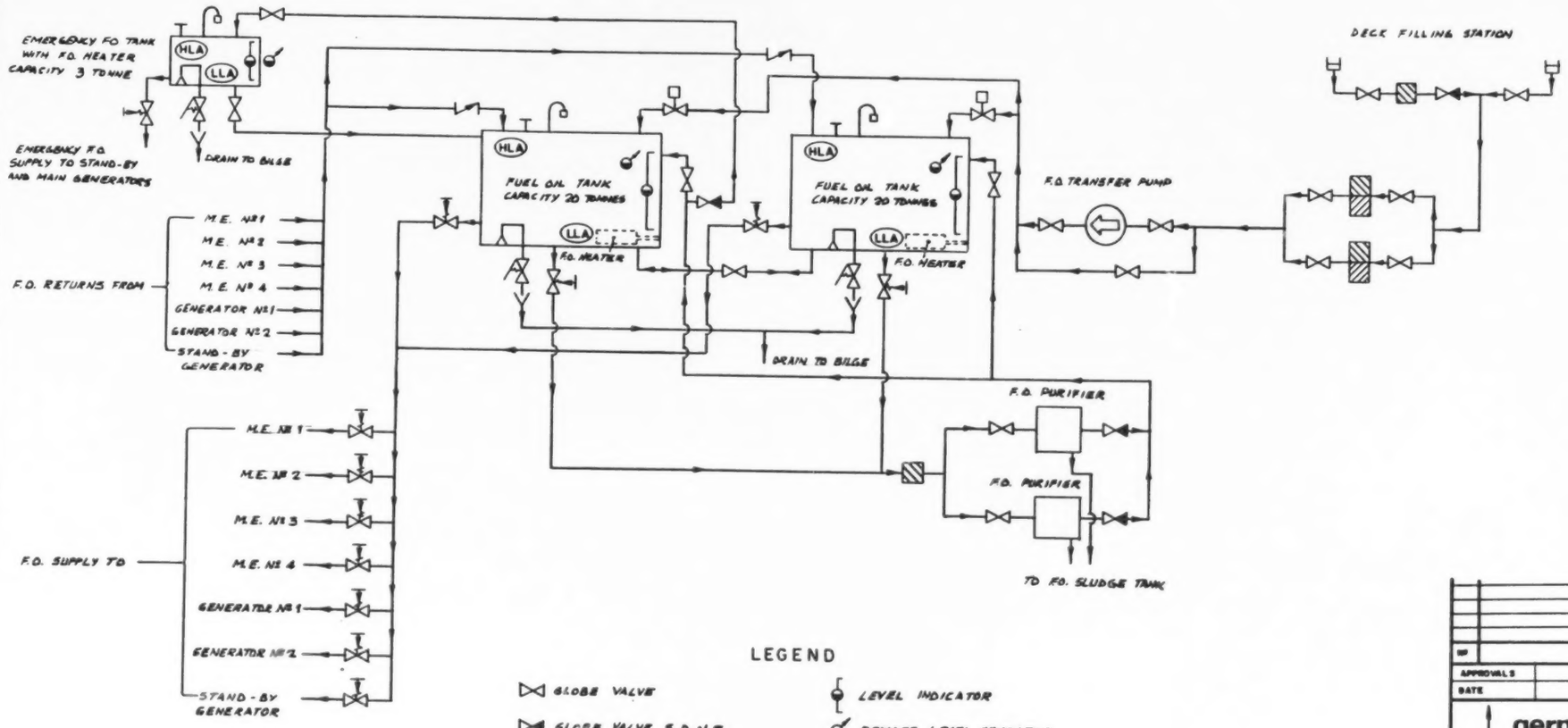
TITLE: GENERAL ARRANGEMENT

SCALE: 1:50 | DATE: JULY 1986

DRAWN BY: G. SMITH

CHECKED BY: G. COLPITTS

DRG. NO: 1-7113-111 | REV. | SHEET NO: 1 OF 1



NOTE
FILTERS, CHECK VALVES, PUMPS, STRAINERS ETC. SUPPLIED ENGINE MOUNTED BY ENGINE MANUFACTURER.

LEGEND

- GLOBE VALVE
- GLOBE VALVE S.D.N.R.
- CHECK VALVE
- QUICK CLOSE, FIRE SAFE VALVE
- SELF CLOSING DRAIN VALVE
- REMOTE OPERATED VALVE
- FILTER
- DUPLEX FILTER
- LEVEL INDICATOR
- REMOTE LEVEL INDICATOR
- (HLA) HIGH LEVEL ALARM
- (LLA) LOW LEVEL ALARM
- VENT FITTED WITH ANTI-FLASH GUARD
- T SOUNDING PIPE

NO	REVISIONS	DATE
APPROVALS		
DATE		

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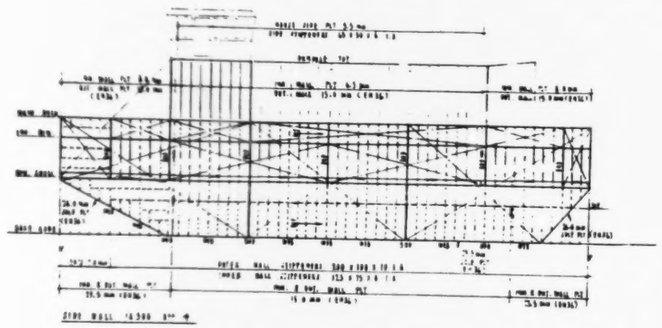
Marine Transportation Consultants
Naval Architects
Montreal Ottawa Vancouver

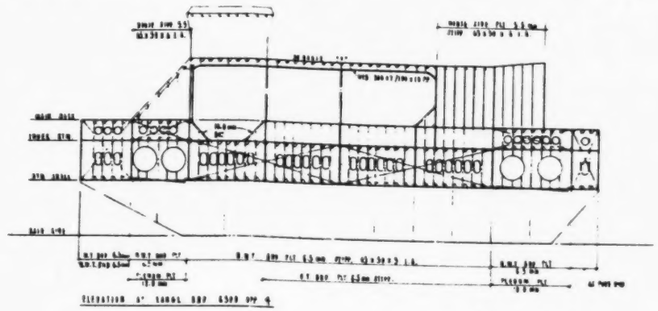
CLIENT: TRANSPORTATION DEVELOPMENT CENTRE

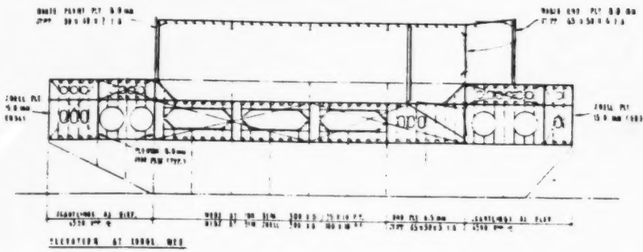
PROJECT: MID-ARCTIC A.C.I.B.

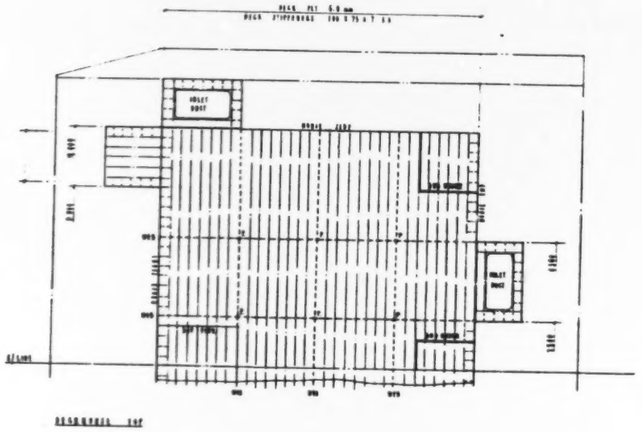
TITLE: FUEL OIL SYSTEM DIAGRAMMATIC

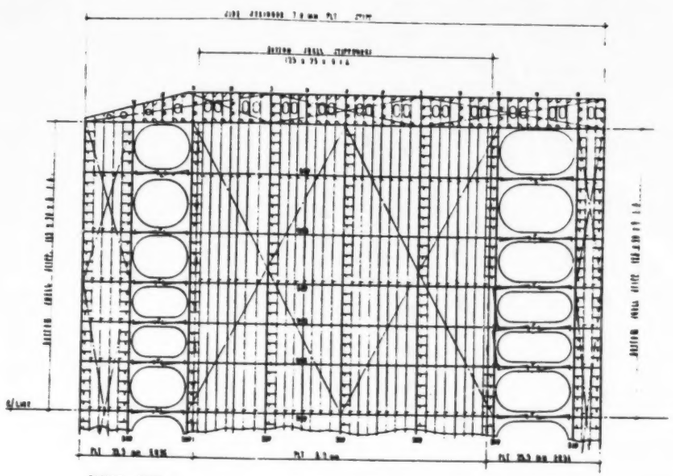
SCALE: N/A	DATE: JUNE '84
DRAWN BY: M.J.SHILLITO	
CHECKED BY: L.EMSLEY	
DRG. NO 1-7113-211 REV.	SHEET NO 1 OF 1

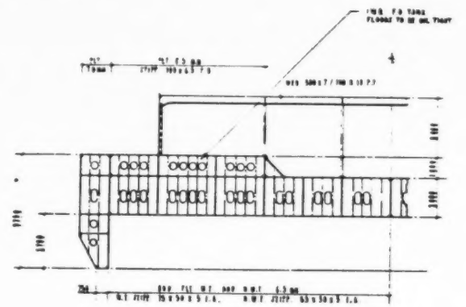


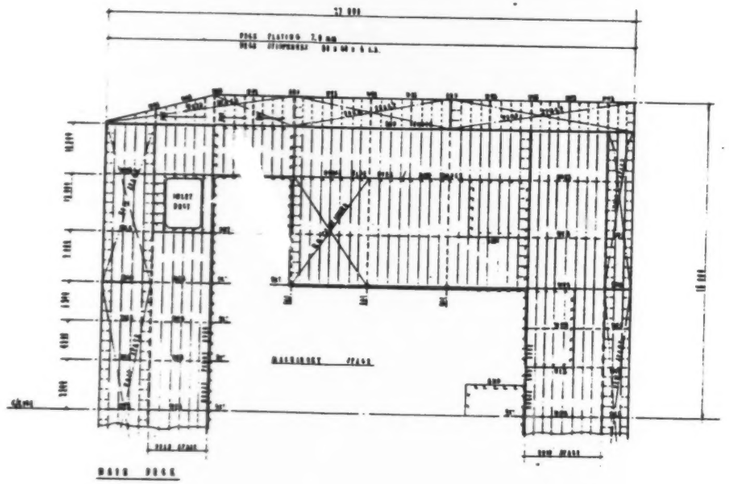


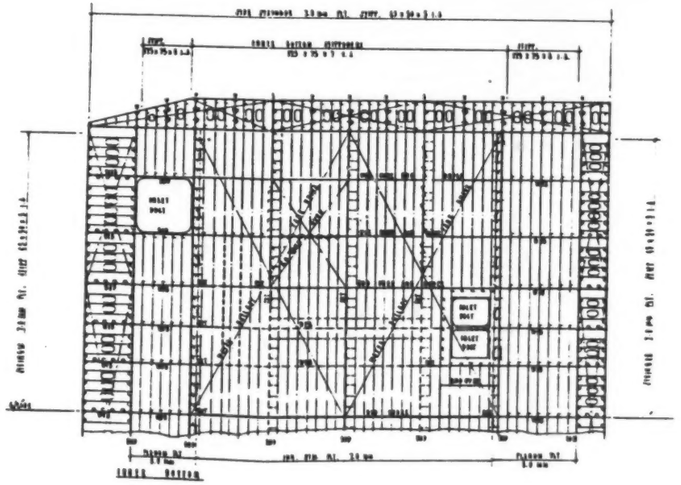


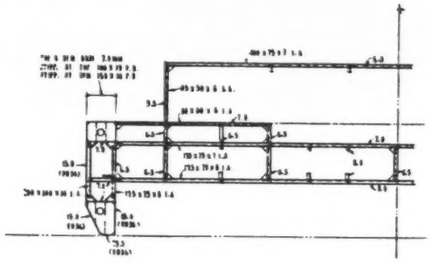












german & milne inc.

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Naval Architects

Montreal Ottawa Vancouver

CLIENT: TRANSPORTATION DEVELOPMENT CENTRE

PROJECT: MID-ARCTIC A.C.I.B. CONCEPTUAL DESIGN

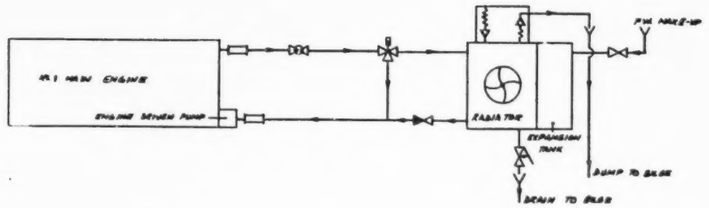
TITLE: STRUCTURAL ARRANGEMENT

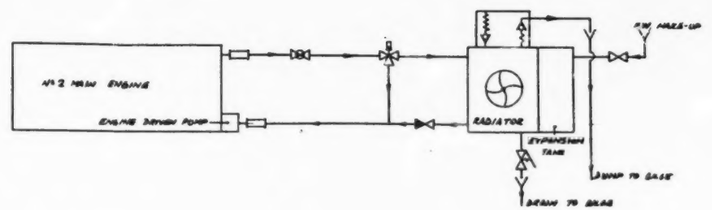
SCALE 1:100 DATE JUNE 84

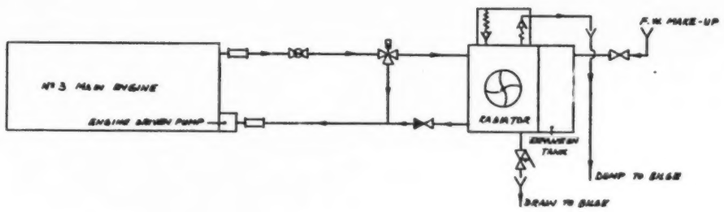
DRAWN BY: B. SHARP

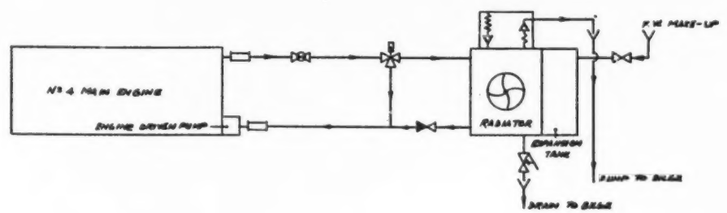
CHECKED BY:

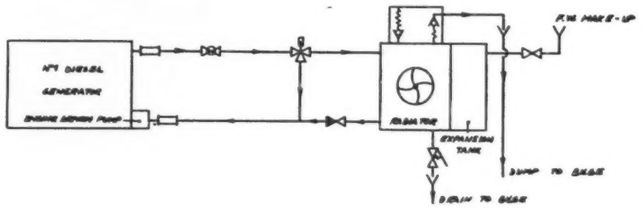
DRG. NO. 1-7103-112 REV. 0 SHEET NO. 1 OF 1

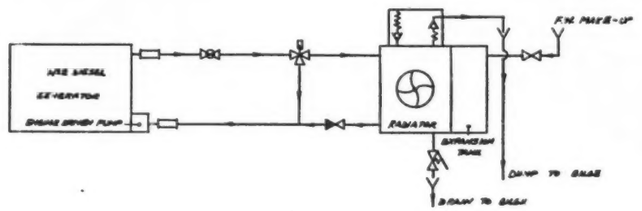


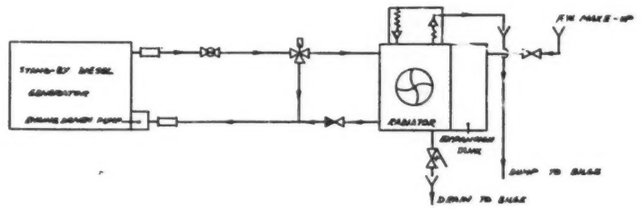












LEGEND

- GLOBE VALVE
- GLOBE VALVE S.D.N.R.
- BUTTERFLY VALVE
- TEMPERATURE CONTROL VALVE
- SELF CLOSING DRAIN VALVE
- FLEXIBLE CONNECTION

NO	REVISIONS	DATE
APPROVALS		
DATE		

german & milne inc.
Marine Transportation Consultants
Naval Architects
Montreal Ottawa Vancouver

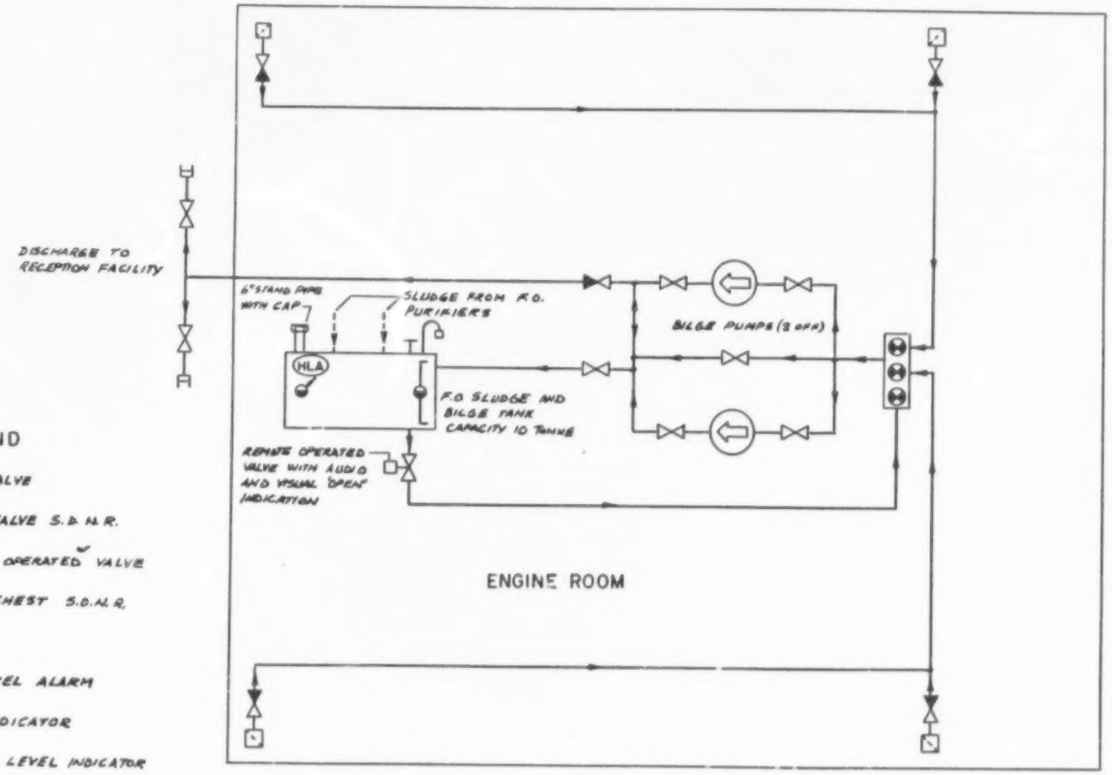
CLIENT: TRANSPORTATION DEVELOPMENT CENTRE

PROJECT: MID-ARCTIC A.C.I.B

TITLE: COOLING WATER DIAGRAMMATIC

SCALE: N/A DATE: JUNE '84
DRAWN BY: M.J.SMILLIE
DESIGNED BY: C.McGLEY

DWG. NO 1-7113-213 REV. SHEET NO 1 OF 1


DISCHARGE TO RECEPTION FACILITY
6" STAND PIPE WITH CAP
SLUDGE FROM F.O. PURIFIER'S
HLA
F.O. SLUDGE AND BILGE TANK CAPACITY 10 TONNE
REMOTE OPERATED VALVE WITH AUDIO AND VISUAL 'OPEN' INDICATION
BILGE PUMPS (2 OFF)
ENGINE ROOM

LEGEND

- GLOBE VALVE
- GLOBE VALVE S.D.N.R.
- REMOTE OPERATED VALVE
- VALVE CHEST S.D.N.R.
- MUD BOX
- HLA HIGH LEVEL ALARM
- LEVEL INDICATOR
- REMOTE LEVEL INDICATOR
- VENT FITTED WITH ANTI-FLASH GUARD
- SOUNDING PIPE

BY	REVISIONS	DATE
APPROVALS		
DATE		

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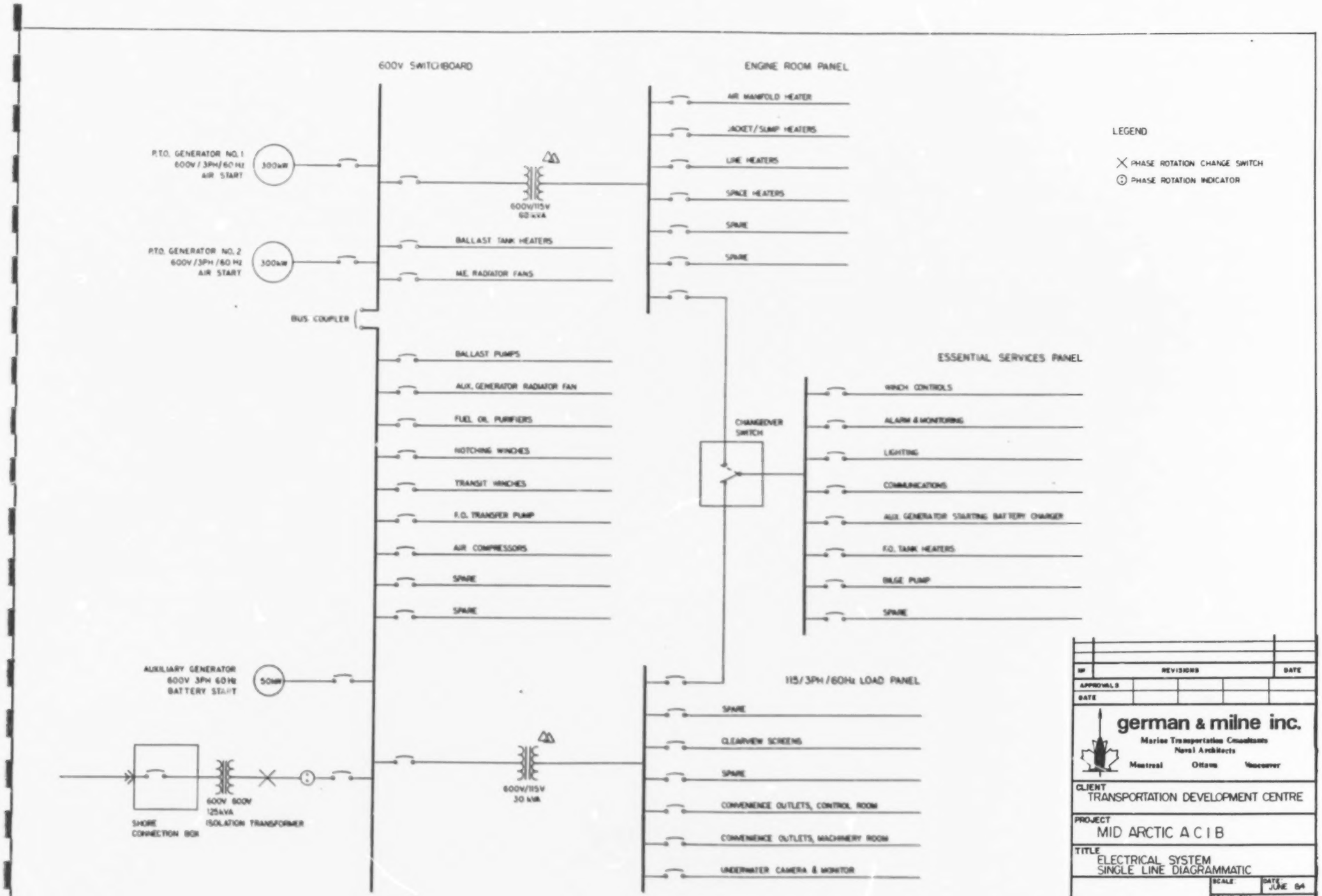
Naval Architects
Montreal Ottawa Vancouver

CLIENT
TRANSPORTATION DEVELOPMENT CENTRE

PROJECT
MID-ARCTIC A.C.I.B.

TITLE
BILGE SYSTEM DIAGRAMMATIC

SCALE N/A	DATE JUNE '84
DRAWN BY M.J. SHILLITO	
CHECKED BY L. EMSLEY	
DRG. NO 1-7113-214 REV.	SHEET NO 1 OF 1



NO	REVISIONS	DATE
APPROVALS		
DATE		

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Marine Transportation Consultants
Naval Architects
Montreal Ottawa Vancouver

CLIENT
TRANSPORTATION DEVELOPMENT CENTRE

PROJECT
MID ARCTIC A C I B

TITLE
ELECTRICAL SYSTEM
SINGLE LINE DIAGRAMMATIC

SCALE:	DATE: JUNE 84
DRAWN BY:	OPS.Lamb
CHECKED BY:	
DRG. NO. 1-7113-311	REV.
SHEET NO. 1 OF 1	

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